2017

H2 Physics

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ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS Higher 2 9749/01

Paper 1 Multiple Choice **Tuesday 19 September 2017**

1 hour

Additional Materials: Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

Write your name, class index number and PDG on the Answer Sheet in the spaces provided.
Shade and write your NRIC/FIN.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{x_o^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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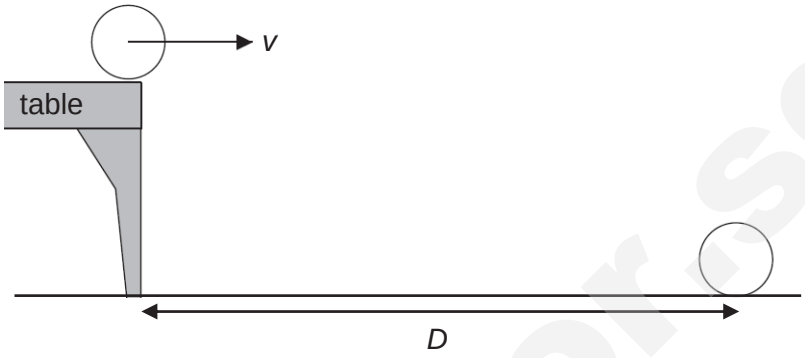
1 What is equivalent to 2000 picovolts?

A 0.002 μJ C **B** 0.02 GV **C** 0.2×10^4 TV **D** 2×10^{-15} MJ C^{-1}

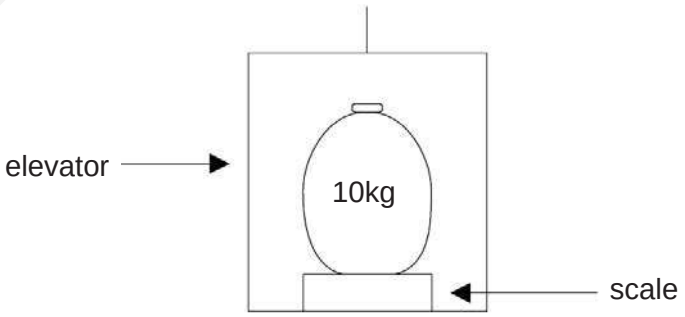
2 A ball rolls off a horizontally table with velocity *v*. It lands on the ground a time *T* later at a distance *D* from the foot of the table as shown in the diagram below. Air resistance is negligible.



A second heavier ball rolls off the table with velocity *v*. Which one of the following is correct for the heavier ball?

	Time to land	Distance from table
A	*T*	*D*
B	*T*	less than *D*
C	less than *T*	*D*
D	less than *T*	less than *D*

3 An elevator is used to either raise or lower sacks of potatoes. In the diagram, a sack of potatoes of mass 10 kg is resting on a scale that is resting on the floor of an accelerating elevator. The scale reads 12 kg.



Which of the following is the best estimate for the acceleration of the elevator?

A 2.0 m s^{-2} downwards.

B 2.0 m s^{-2} upwards.

C 1.2 m s^{-2} downwards.

D 1.2 m s^{-2} upwards.

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4 Two similar spheres, each of mass m and travelling with speed v, are moving towards each other.



The spheres have a head-on elastic collision.

Which statement is correct?

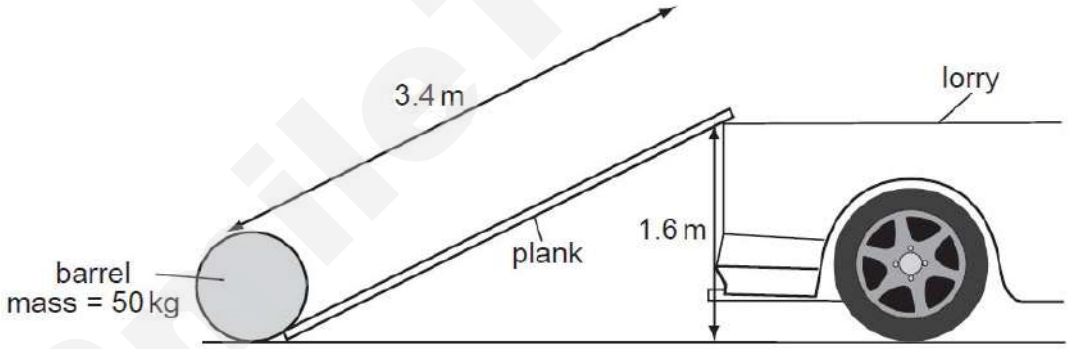
A The spheres stick together on impact.

B The total kinetic energy after impact is mv^2.

C The total kinetic energy during collision is mv^2.

D The total momentum before impact is $2mv$.

5 A barrel of mass 50 kg is loaded onto the back of a lorry 1.6 m high by pushing it up a smooth plank 3.4 m long.



What is the minimum work done?

A 80 J **B** 170 J **C** 780 J **D** 1700 J

6 A ball is falling at terminal speed in still air. The forces acting on the ball are upthrust, viscous drag and weight.

What is the order of increasing magnitude of these three forces?

A viscous drag → weight → upthrust

B viscous drag → upthrust → weight

C weight → viscous drag → upthrust

D upthrust → viscous drag → weight

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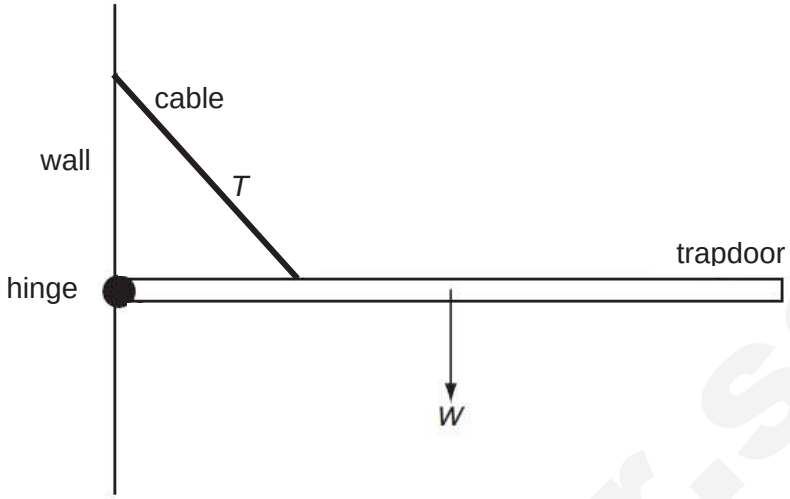
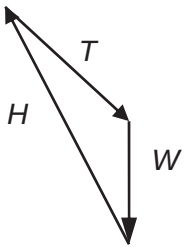
7 A hinged trapdoor is held closed in the horizontal position by a cable. Three forces act on the trapdoor: weight *W* of the door, tension *T* in the cable and a force *H* at the hinge.

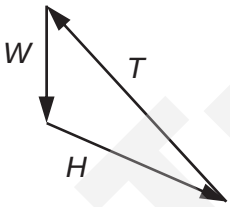


Which vector triangle could represent the forces acting on the trapdoor?

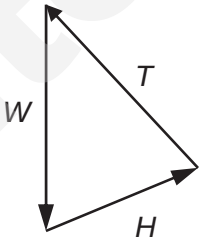
A



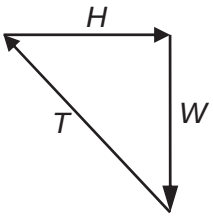
B



C



D



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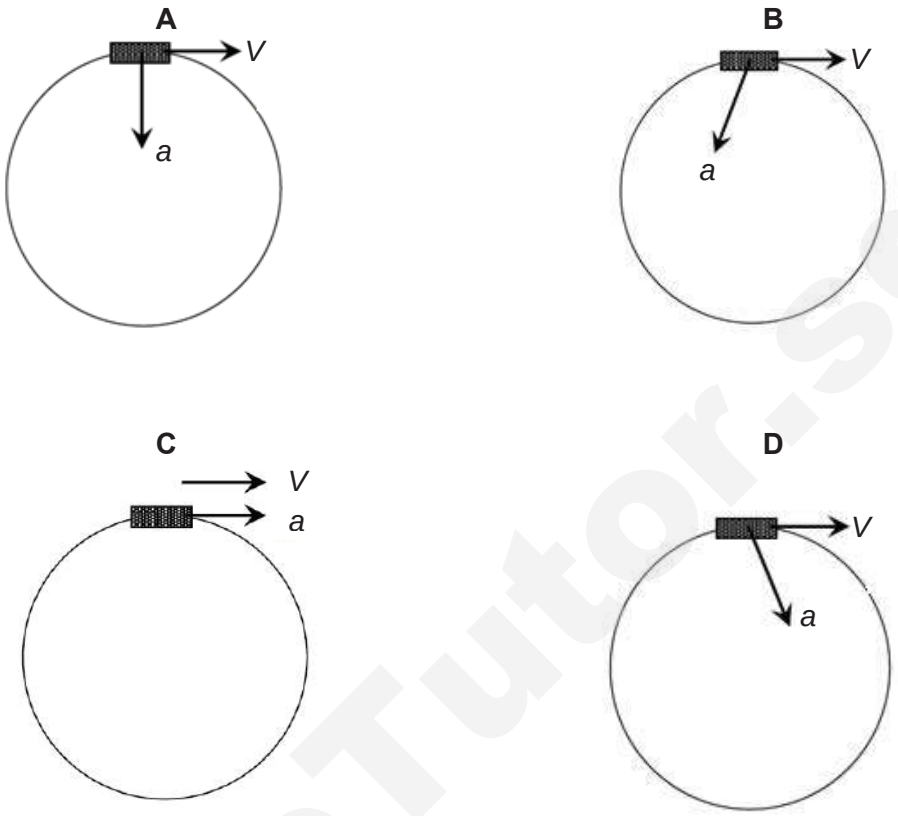
8 A drone is performing a vertical circular path stunt for its audience on the ground. Which diagram shows the resultant acceleration *a* acting on the drone at the instant where its velocity is *V* and speeding up?



9 A CD-ROM is spinning about its central axis at a constant speed. At a point that is 0.030 m from the centre of the disc, the centripetal acceleration is 120 m s^{-2}. What is the linear speed of a point that is 0.050 m from the centre of the disc?

A 1.90 m s^{-1} **B** 2.24 m s^{-1} **C** 3.16 m s^{-1} **D** 6.32 m s^{-1}

10 A spacecraft orbiting a planet in uniform circular motion has an antenna detached gently from it. Neglecting air resistance, which statement best describes the motion of this detached antenna?

A It will move off in a straight line away from the planet.

B It will take a parabolic path into the planet.

C It will drop straight down into the planet.

D It will continue to orbit in uniform circular motion.

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11 Water has a higher specific heat capacity than iron. If the same amount of heat is given to equal masses of water and iron that are initially at the same temperature, which of the following is true?

A The iron is now warmer than the water.

B The water is now warmer than the iron.

C The temperature of the iron rises faster than the water but both reach the same final temperature.

D The temperature of the water rises faster than the iron but both reach the same final temperature.

12 When a gas is heated uniformly inside a sealed rigid cylinder, which of the following does not change?

A The average number of molecules hitting the cylinder wall per second.

B The average force acting on the gas molecules by the cylinder wall.

C The average distance between the gas molecules.

D The average speed of the gas molecules.

13 A sample of an ideal gas may (i) expand at constant pressure or (ii) expand at constant temperature. What is the net flow of heat into the gas from the exterior?

A Negative in each case.

B Positive in each case.

C Zero for (i) and positive for (ii).

D Positive for (i) and zero for (ii).

14 A student is investigating the specifications of a camera shutter. He used a camera to photograph a simple pendulum bob that is moving in front of a horizontal scale. The extreme positions of the bob were at 600 mm and 700 mm marks.

The photograph showed that the bob moved from the 650 mm mark to the 675 mm mark when the shutter was opened. If the period of the pendulum was 2 s, what is the time that the shutter has remained opened?

A 1 s **B** 0.50 s **C** 0.25 s **D** 0.167 s

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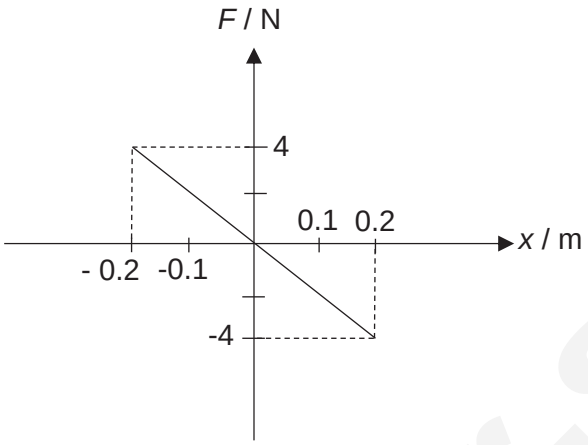
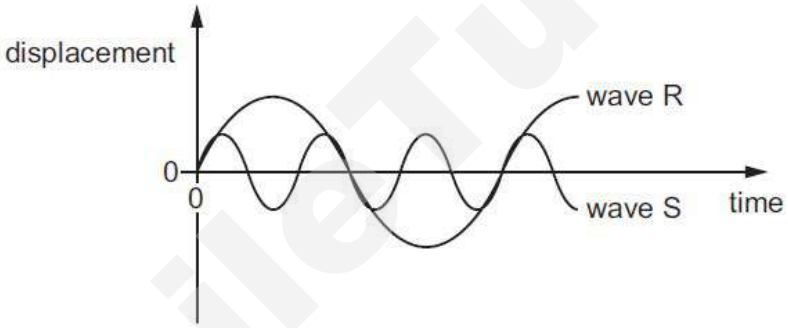
15 A body of mass 0.20 kg is subjected to a force F which varies with its displacement x from a fixed point as shown below.



What is the maximum speed of its motion in m s^{-1}?

A 2.0 **B** 10 **C** 20 **D** 100

16 The diagram shows two waves R and S.



Wave R has an amplitude of 8 cm and a period of 30 ms.

What are the amplitude and the period of wave S?

	amplitude / cm	period / ms
A	2	10
B	2	90
C	4	10
D	4	90

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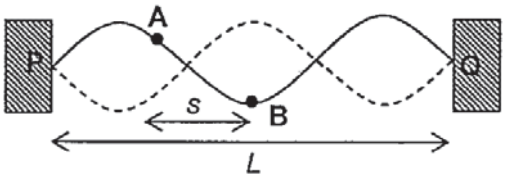
17 A guitar string of length L is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown.



Two particles **A** and **B** on the string are separated by a distance s. The maximum kinetic energies of **A** and **B** are K_A and K_B respectively.

Which of the following gives the correct phase difference and maximum kinetic energies of the particles?

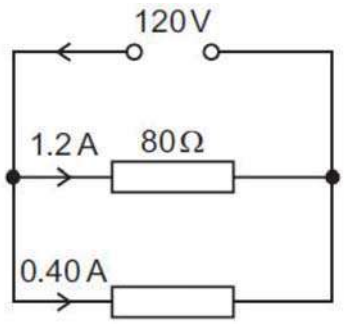
	Phase difference	Maximum kinetic energy
A	$\left(\frac{3s}{2L}\right) \times 360°$	$K_A < K_B$
B	$\left(\frac{3s}{2L}\right) \times 360°$	same
C	180°	$K_A < K_B$
D	180°	same

18 Monochromatic light of wavelength 5.30×10^{-7} m is incident normally on a diffraction grating. The first order maximum is observed at an angle of 15.4° to the direction of the incident light.

What is the angle between the first and second order diffraction maxima?

A 7.7° **B** 15.4° **C** 16.7° **D** 32.1°

19 The electromotive force of a power supply is 120 V. It delivers a current of 1.2 A to a resistor of resistance 80 Ω and a current of 0.40 A to another resistor, as shown.



What is the internal resistance of the power supply?

A 15 Ω **B** 20 Ω **C** 60 Ω **D** 75 Ω

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20 There is a current in a resistor for an unknown time.

Which two quantities can be used to calculate the energy dissipated by the resistor?

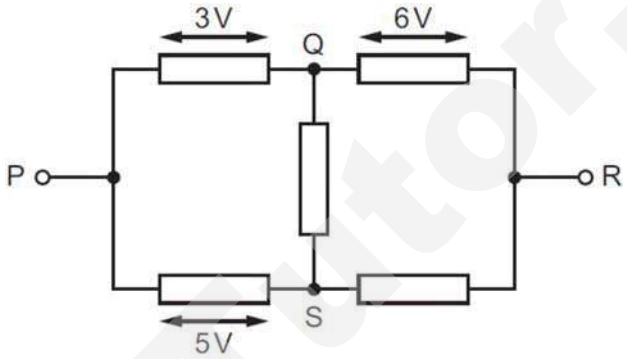
A The current in the resistor and the potential difference across the resistor.

B The resistance of the resistor and the current in the resistor.

C The total charge passing through the resistor and the potential difference across the resistor.

D The total charge passing through the resistor and the resistance of the resistor.

21 There is a current from P to R in the resistor network shown.



The potential difference (p.d.) between P and Q is 3 V.

The p.d. between Q and R is 6 V.

The p.d. between P and S is 5 V.

Which row in the table is correct?

	p.d. between Q and S	p.d. between S and R
A	2 V	4 V
B	2 V	10 V
C	3 V	4 V
D	3 V	10 V

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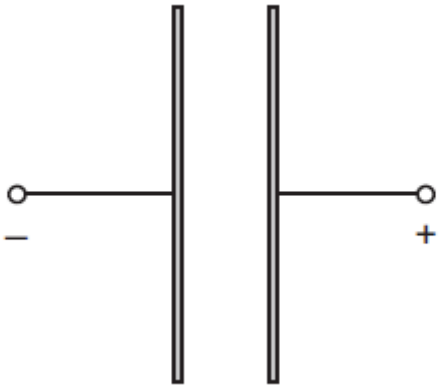
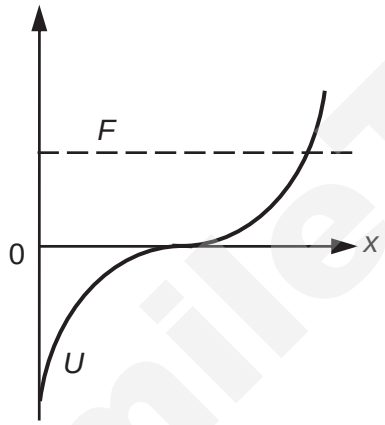
22 Two oppositely-charged parallel plates are arranged as shown.



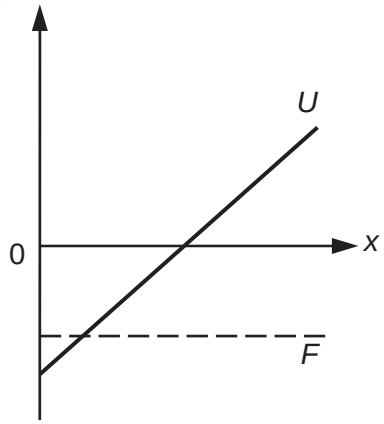
An electron is released from rest from the surface of the negatively-charged plate. The electron travels from the negatively-charged plate towards the positively-charged plate.

Which graph shows how the force *F* and electric potential energy *U* of the electron vary with its distance x from the negative plate?

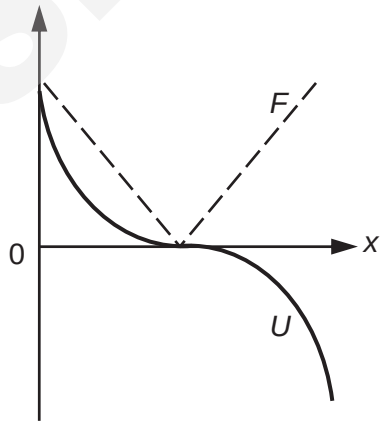
A



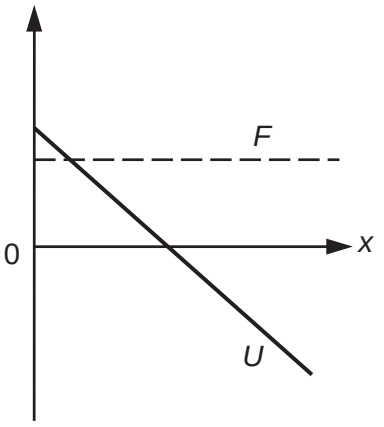
B



C



D



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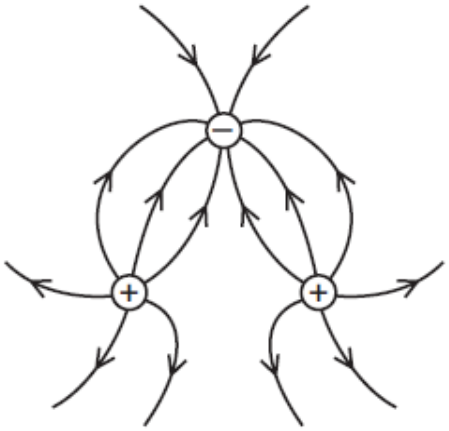
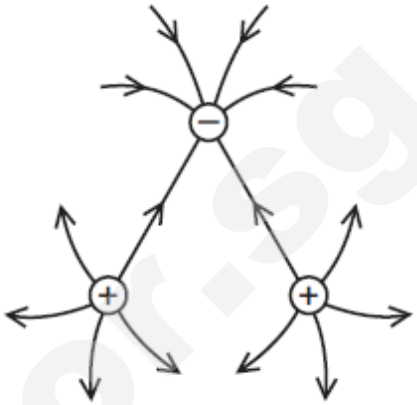
23 Two positive charges and one negative charge, all of equal magnitude, are set at the corners of an equilateral triangle.

Which diagram best represents the electric field surrounding the charges?

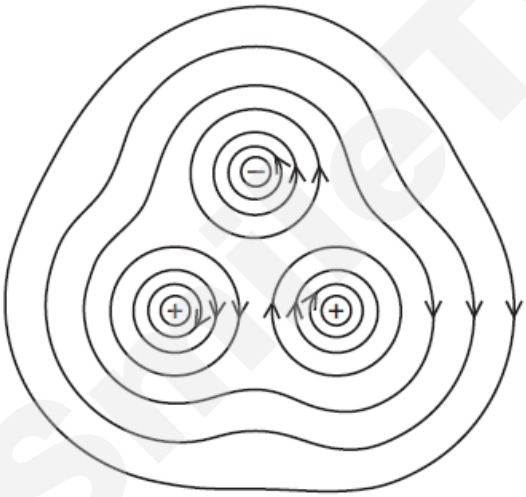
A



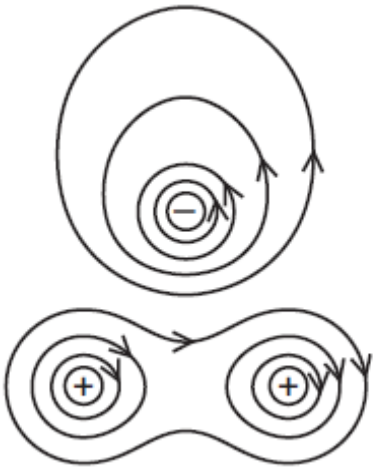
B



C



D



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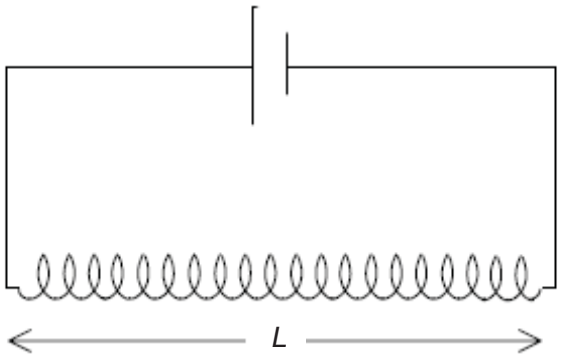
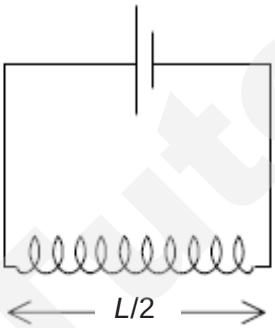
24 The diagram shows a long solenoid of length *L* connected to a battery of negligible internal resistance. The magnetic field strength at the centre of the solenoid is *T*.



The solenoid is now disconnected from the battery and cut in half and one of the halves is reconnected to the battery as shown below.



What is the best estimate of the field strength at the centre of this solenoid?

A 0.5*T* **B** *T* **C** 2*T* **D** 4*T*

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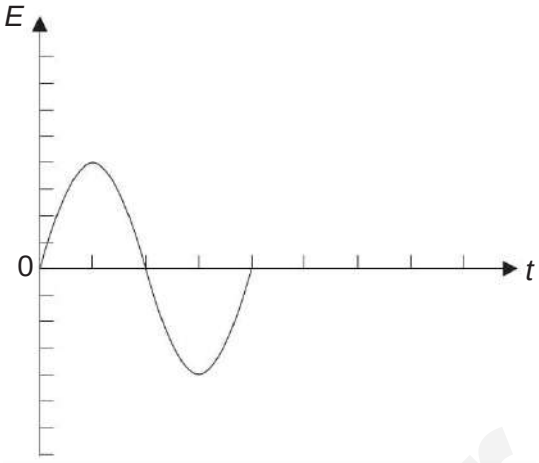
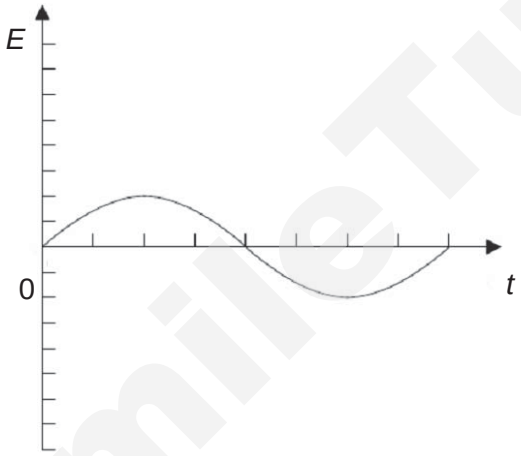
25 When a coil is rotated in a uniform magnetic field at a certain frequency, the variation with time t of the induced e.m.f. E is shown below.

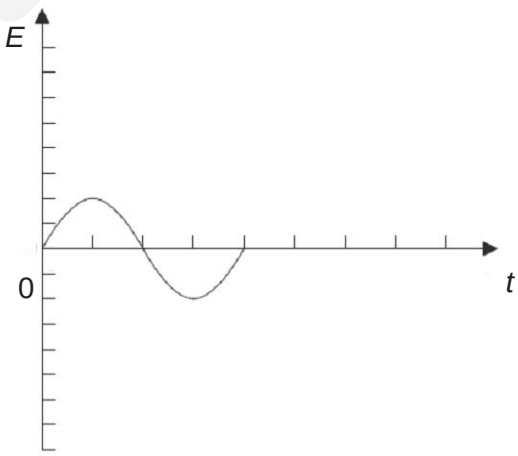


The frequency of rotation of the coil is reduced to **one half** of its initial value. Which **one** of the following graphs correctly shows the new variation with time t of the induced e.m.f. E?

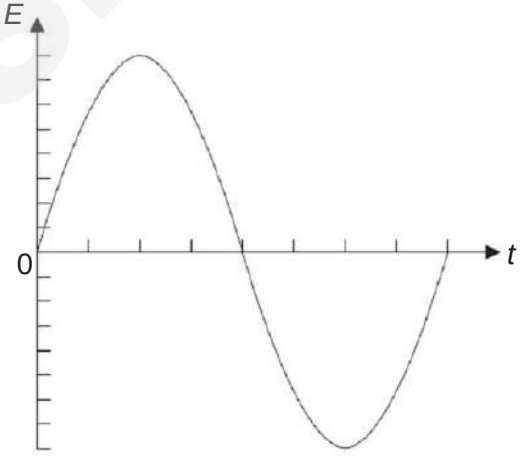
A



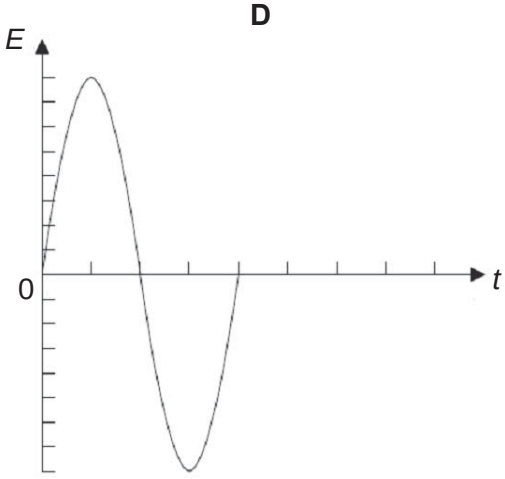
B



C



D



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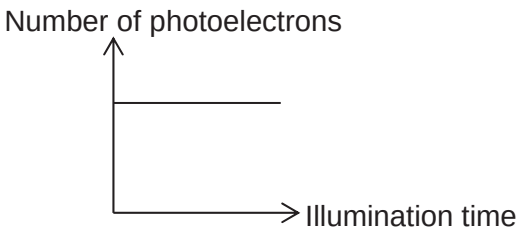
26 An a.c. supply is connected to a resistor. If the r.m.s. voltage output of the supply is doubled, by what factor would the power dissipated in the resistor increase?

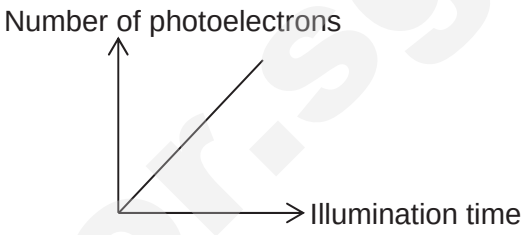
A 1 **B** $\sqrt{2}$ **C** 2 **D** 4

27 When electromagnetic radiation of frequency *f* falls on a particular metal surface, photoelectrons are emitted. Which graph is obtained when the intensity of the electromagnetic radiation is kept constant?

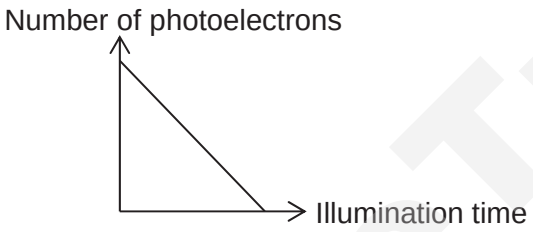
A



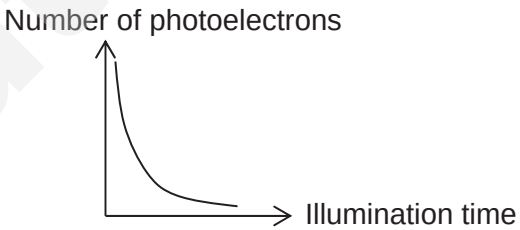
B



C



D



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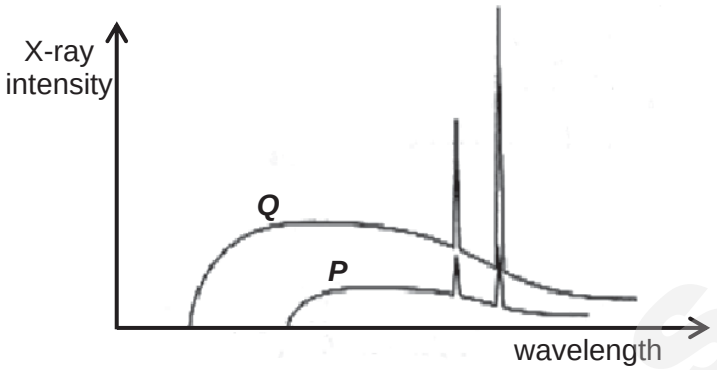
28 X-ray spectra are taken from two X-ray tubes P and Q. The intensity of the X-rays is plotted against the wavelength in both cases and is shown below.



What deduction can be made from these plots?

A X-ray tube Q has the higher voltage applied to it and the target material in both tubes are different.

B X-ray tube Q has the higher voltage applied to it and the target material in both tubes is the same.

C X-ray tube P has the higher voltage applied to it and the target material in both tubes is the same

D X-ray tube P has the higher voltage applied to it and the target material in both tubes are different.

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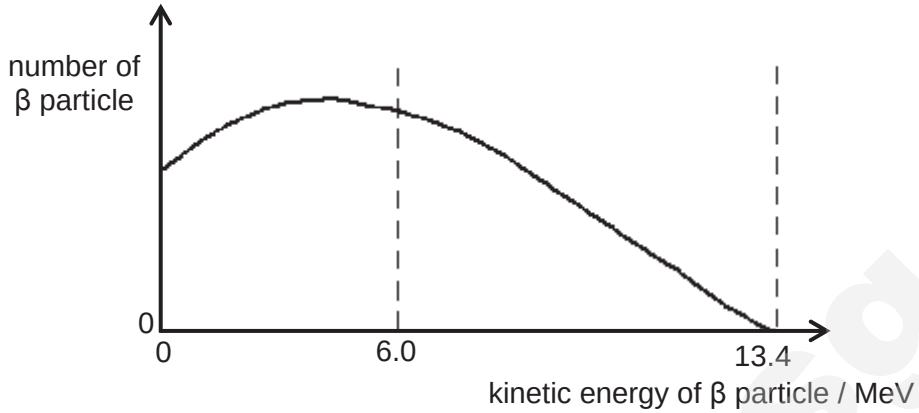
29 The beta spectrum for ^{12}B decay is as shown below.



The kinetic energy of an emitted β particle is 6.0 MeV. What is the approximate energy of the associated neutrino?

A 6.0 MeV

B 7.4 MeV

C 9.7 MeV

D 13.4 MeV

30 Nuclide X decays with a half-life of 15 days to stable nuclide Y. At a particular time, *t*, the ratio of the number of nuclides X to the number of nuclides Y in a sample is 1:1.

How long after time *t* will the ratio in the sample be 1:3?

A 15 days

B 30 days

C 45 days

D 60 days

End of Paper

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Name: _____ ( ) PDG: _____/ 16

ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS Higher 2 9749/02

Paper 2 Structured Questions **Tuesday 12 September 2017**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, glue or correction fluid.

The use an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Significant Figure	
Total (80 marks)	

This document consists of **22** printed pages

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{x_o^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 In 2010, an iron cannon and some iron cannon balls were discovered offshore in the United Kingdom after sitting on the seabed for a few hundred years.

(a) An experiment is performed to determine the density ρ of an iron cannon ball. The average of the measurements, with their uncertainties, are shown in Fig 1.1.

Mass, m / kg	Diameter, d / cm
79.72 ± 0.01	26.7 ± 0.1

Fig 1.1

(i) Show that the density of iron, ρ is 7999 kg m^{-3}.

[1]

(ii) Calculate the actual uncertainty in ρ.

actual uncertainty in ρ =…….. kg m^{-3} [2]

(iii) State the value of ρ and its actual uncertainty to the appropriate number of significant figures.

ρ = ……±……..kg m^{-3} [1]

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(b) One possible way to raise the iron cannon from the seabed is to use a lifting bag, which may be attached to the iron cannon and then partially inflated with air, as shown in Fig. 1.2.

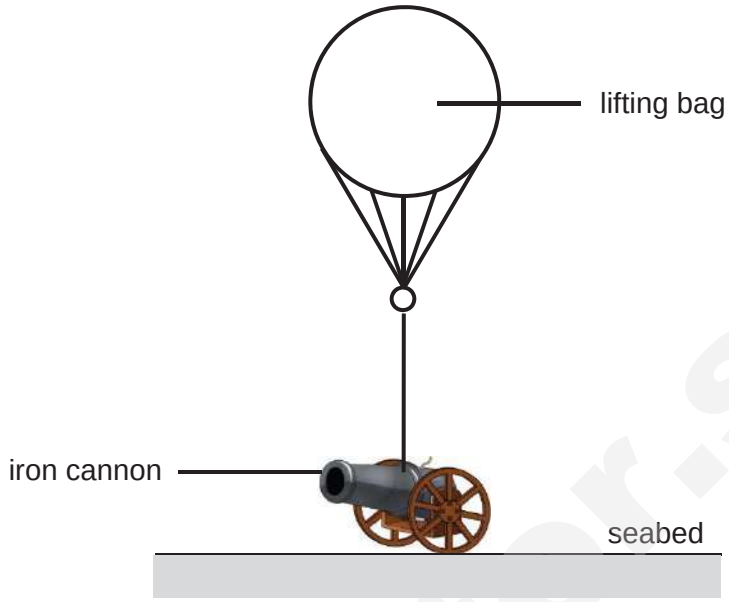

Fig. 1.2

(i) The submerged iron cannon of mass 800 kg is attached to a lifting bag of negligible volume and mass. Using the data in part **(a)(i)**, estimate the initial acceleration of the cannon when 0.70 m^3 of air is suddenly released into the bag. The density of the seawater is 1050 kg m^{-3}.

acceleration = ……m s^{-2} [3]

(ii) Explain why air has to be released continuously from the lifting bag as the iron cannon rises from the seabed to the surface so that a constant speed of ascent is maintained.

……

……

……

……

…… [3]

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2 **(a)** Gas, R, is trapped in a vessel by a column of liquid PQ as shown in Fig 2.1 below. Length of the liquid column can be increased by adding more liquid to PQ.

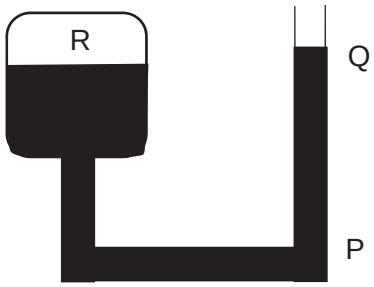

Fig 2.1

Using the kinetic theory, explain how the pressure of the gas R is increased,

(i) when the volume of R remain unchanged and its temperature increases.

……..

……..

……..

……..

……..

…….[3]

(ii) when the temperature of R remain unchanged and its volume decreased slightly.

……..

……..

……..

…….[2]

(b) There is about one hydrogen atom per cm^3 in outer space, where the temperature (in the shade) is about 3.5 K. The mass of a hydrogen atom is 1 *u*.

Calculate

(i) the rms speed of these atoms.

rms speed = …….. $m\ s^{-1}$ [3]

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(ii) the pressure exerted by these atoms.

pressure = …… Pa [3]

3 **(a)** A mass of 170 g oscillates with simple harmonic motion. Fig. 3.1 shows the variation with time *t* of the displacement *y* of the mass.

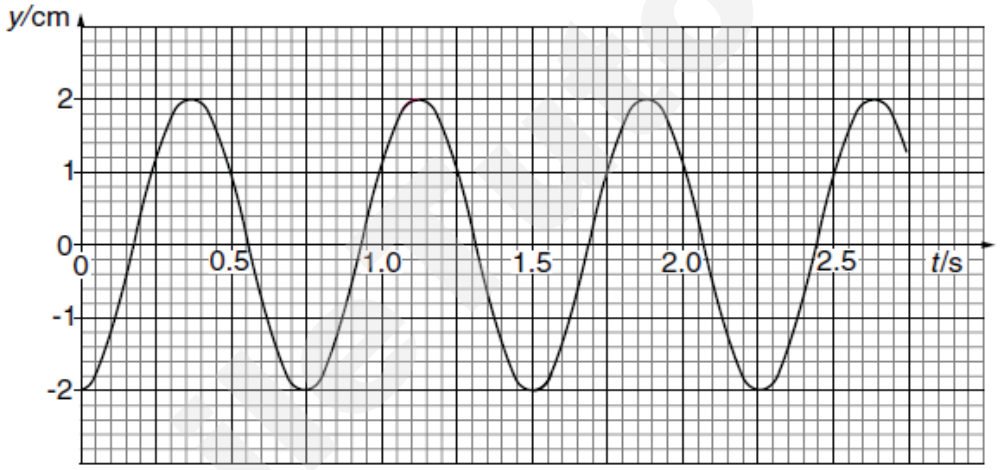

Fig. 3.1

(i) Explain what is meant by *simple harmonic motion*.

……

……

…… [2]

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(ii) On Fig. 3.2, draw a graph showing the variation with displacement y of the potential energy E_p of the mass

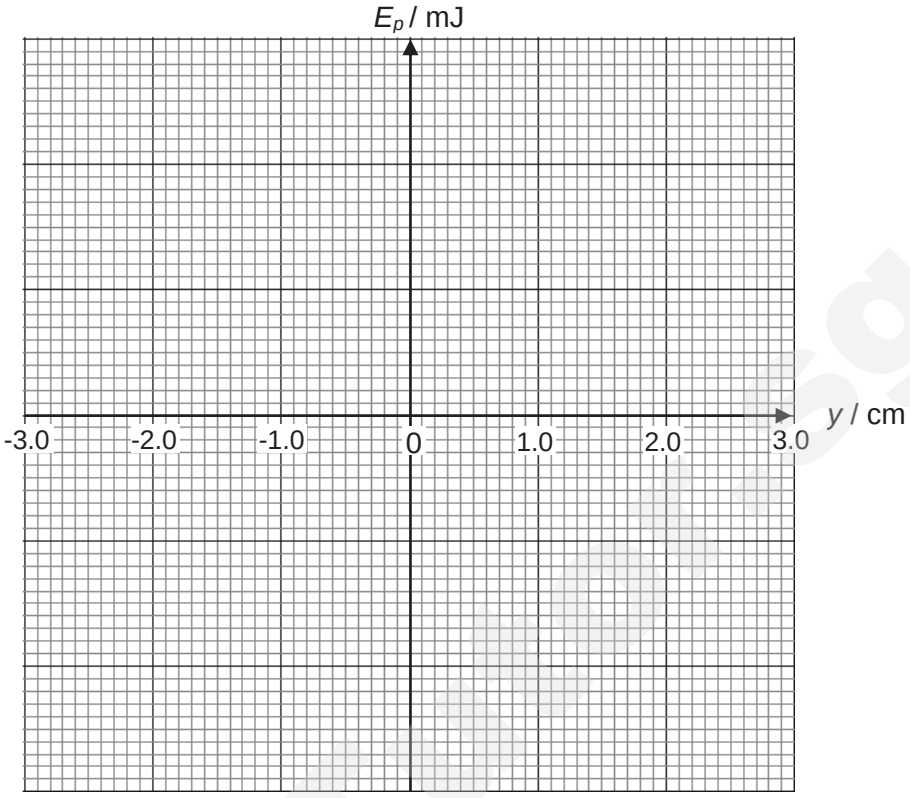

Fig. 3.2

[3]

(b) The drums of an automatic washing machine are suspended from the casing by springs, at the top and bottom, as shown in Fig. 3.3. The inner drum rotates within the outer drum at variable speeds according to the washing programme.

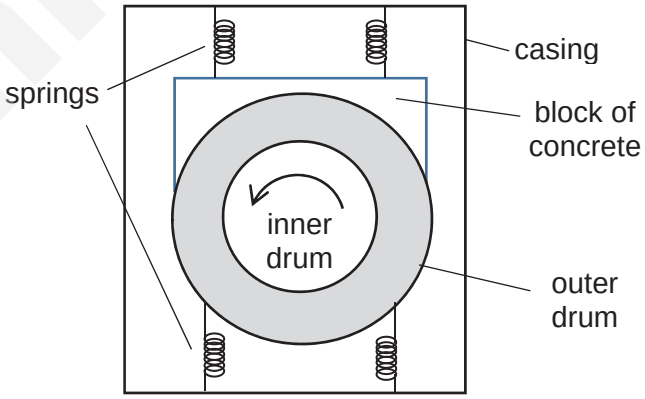

Fig. 3.3

The total mass of the drums is 20 kg. A block of concrete of mass 20 kg is added to the outer drum. The natural period of oscillation of the system is 1.6 s. The period of oscillation T of the system is given by $T = 2\pi\sqrt{\frac{M}{k}}$, where M is the total mass of the load in the system and k is the effective spring constant of the springs.

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When the washing machine enters the spin part of the washing programme, it starts from rest and its rotational speed increases gradually. As the speed increases, the system is observed to oscillate with increasing amplitude which reaches a maximum value of 5.0 cm before decreasing again at higher speeds.

(i) Calculate the number of revolutions per second of the drum when the maximum amplitude of oscillation is observed.

number of revolutions per second = ... [1]

(ii) Explain

1. why the system oscillates when the inner drum is rotated,

.....

..... [1]

2. and why the amplitude reaches a maximum.

.....

..... [1]

(iii) On Fig. 3.4, sketch a graph showing how the amplitude varies with frequency of rotation of the inner drum.

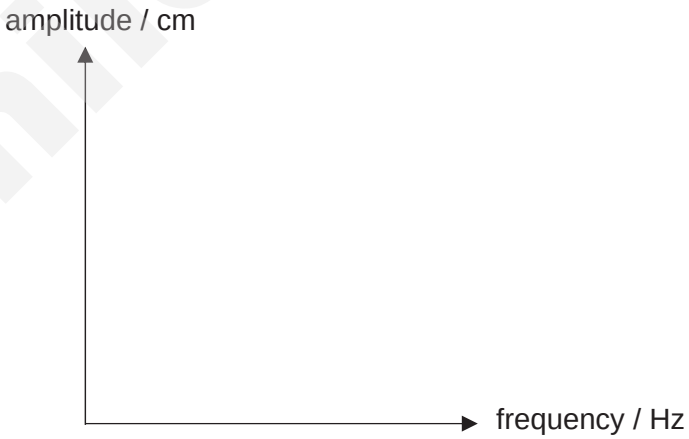

Fig. 3.4 [2]

(iv) State and explain one effect on the machine without the block of concrete fixed to the drum.

.....

.....

..... [2]

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4 **(a)** A cell of e.m.f. E = 3.0 V and internal resistance r = 0.50 Ω is connected to three bulbs X, Y and Z as shown in the circuit of Fig. 4.1.

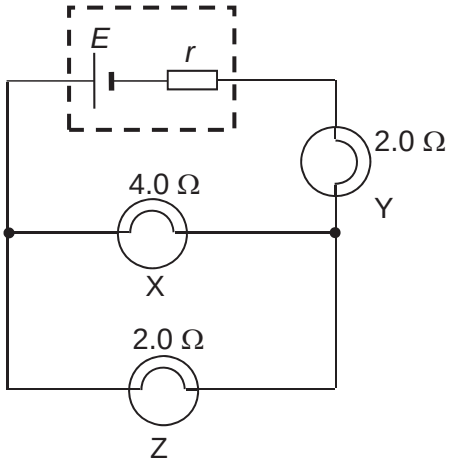

Fig. 4.1

(i) Calculate the effective resistance of the three bulbs in the circuit of Fig. 4.1.

effective resistance = ……Ω [2]

(ii) List the light bulbs X, Y and Z in order of *increasing* brightness.

in order of increasing brightness: …… [1]

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(b) The circuit of Fig. 4.1 was connected to a potentiometer that is made up of a 6.0 V battery in series with a resistance R = 1.0 Ω and a uniform wire **AB** of length 100.0 cm and resistance 2.0 Ω (see Fig. 4.2).

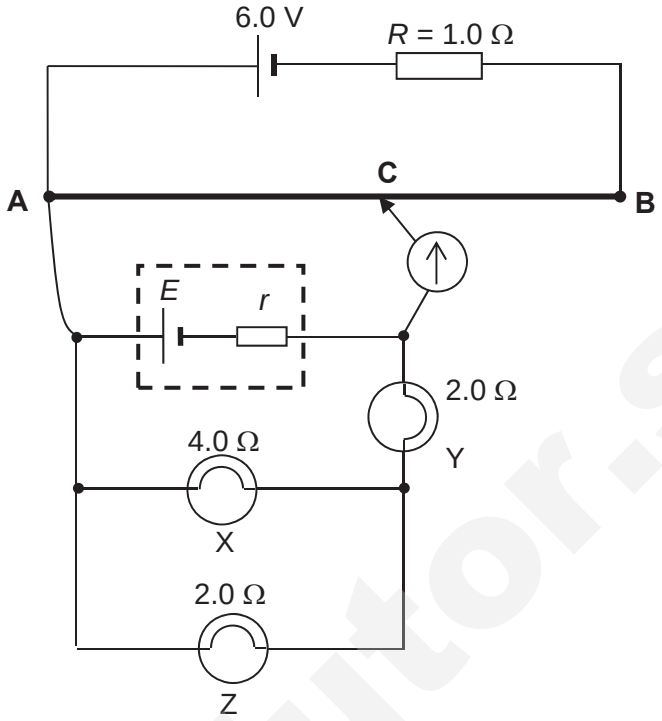

Fig. 4.2

(i) Show that the potential difference across **AB** is 4.0 V when the galvanometer shows null deflection

. [1]

(ii) Determine the balance length **AC**.

balance length **AC** = ……cm [3]

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(iii) Explain how, if at all, the balance length **AC** will be affected if bulb X is replaced by a bulb of lower resistance.

……

……

……

……

…… [2]

5 **(a)** A current-carrying solenoid XY is placed near to a small coil, as shown in Fig. 5.1.

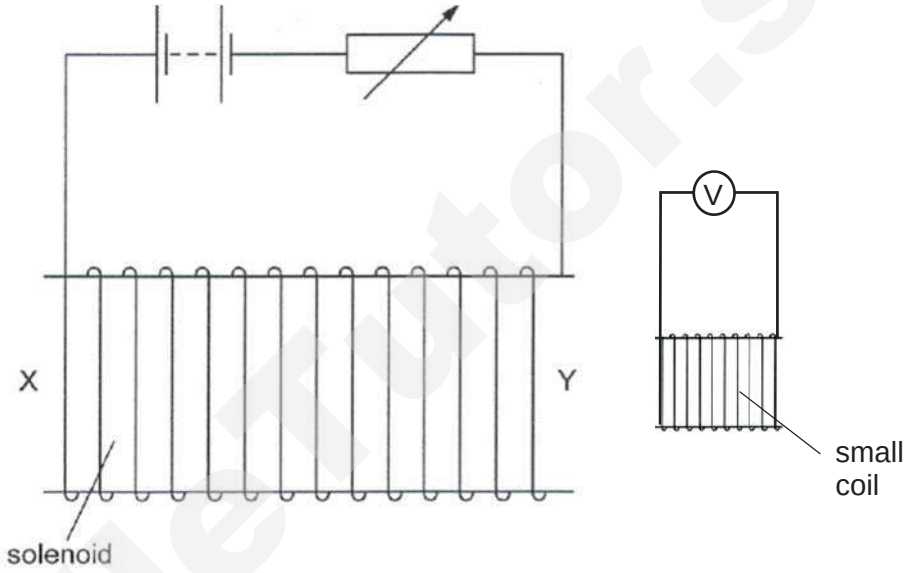

Fig. 5.1

The small coil is connected to a sensitive voltmeter.

(i) State the direction, XY or YX, of the magnetic field in the solenoid.

direction = …… [1]

(ii) The resistance of the variable resistor is changed so that the current in the solenoid increases.

1. State Faraday's law of electromagnetic induction and use it to explain why a reading is recorded on the voltmeter.

……

……

……

……[2]

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2. State Lenz's law and hence explain the direction of the induced current in the small coil.

On Fig. 5.1, mark the direction of this induced current.

……

……

……

……

……[3]

(iii) The current in the solenoid is now made to vary as shown in Fig. 5.2.

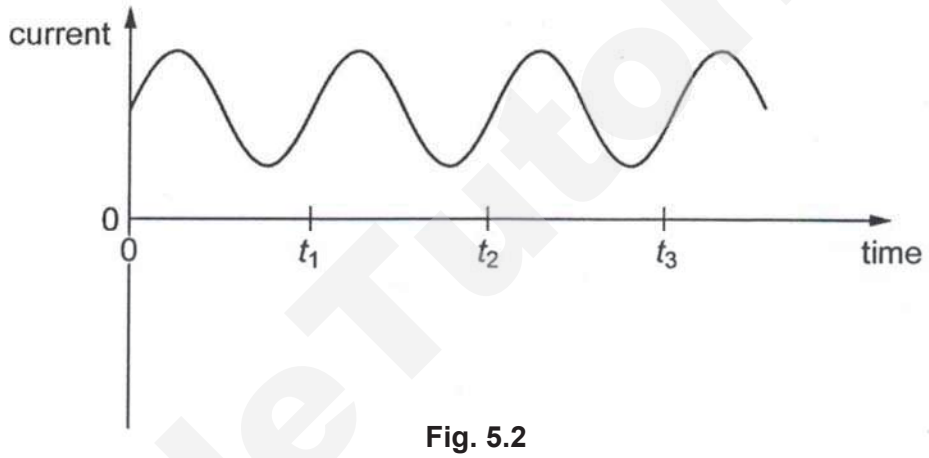

Fig. 5.2

On Fig. 5.3, show the variation with time of the e.m.f. induced in the small coil.

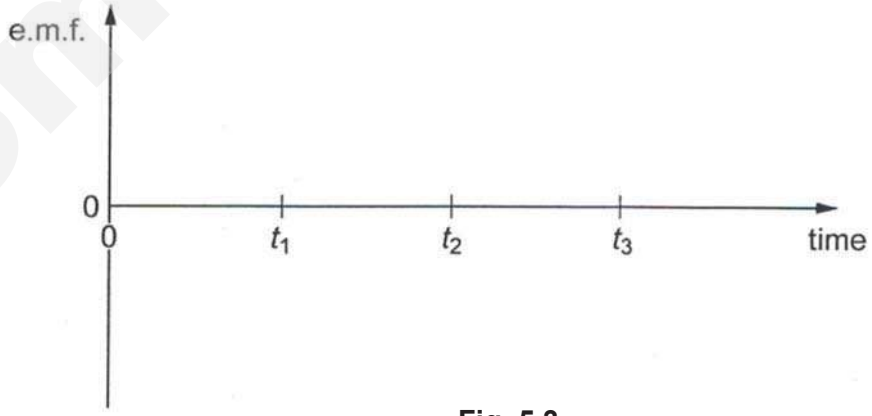

Fig. 5.3

[2]

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(b) Fig. 5.4 is the circuit diagram for a half-wave rectifier.

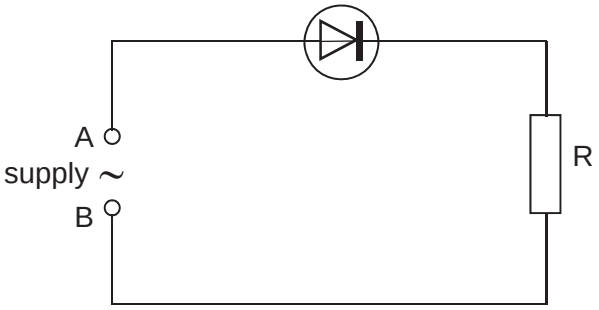

Fig. 5.4

The supply to the diode is rated as 50 Hz, 6.0 V, 1.5 W. Fig. 5.5 shows the trace of the variation with time of the potential at terminal A with respect to B when an oscilloscope is connected across the supply.

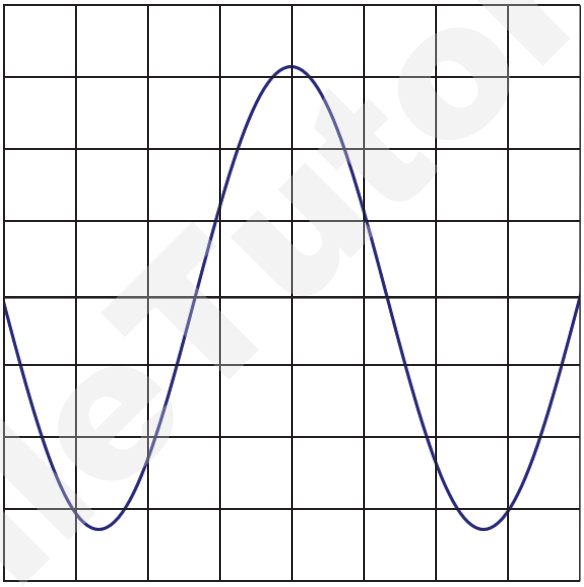

Fig. 5.5

(i) Determine the r.m.s. current the supply can provide when it is operating at 6.0 V.

r.m.s. current = ……A [1]

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(ii) On Fig. 5.6, draw a line to represent the corresponding trace seen on the oscilloscope across the load resistor R. [1]

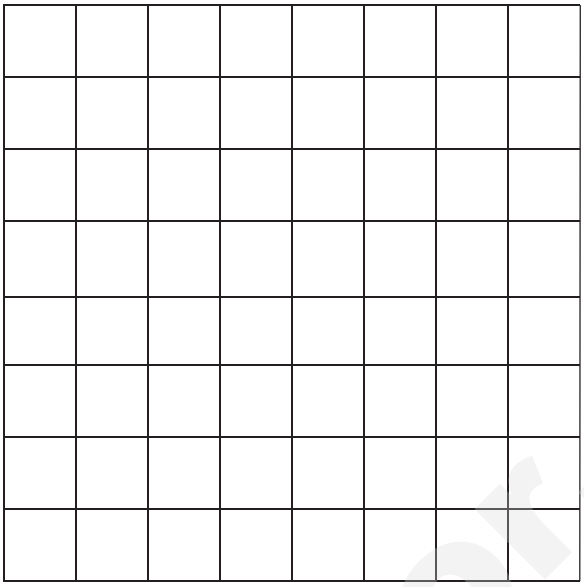

Fig. 5.6

6 **(a)** A parallel beam of electrons, all travelling at the same speed, is incident normally on a carbon film. The scattering of the electrons by the film is observed on a fluorescent screen, as illustrated in Fig. 6.1.

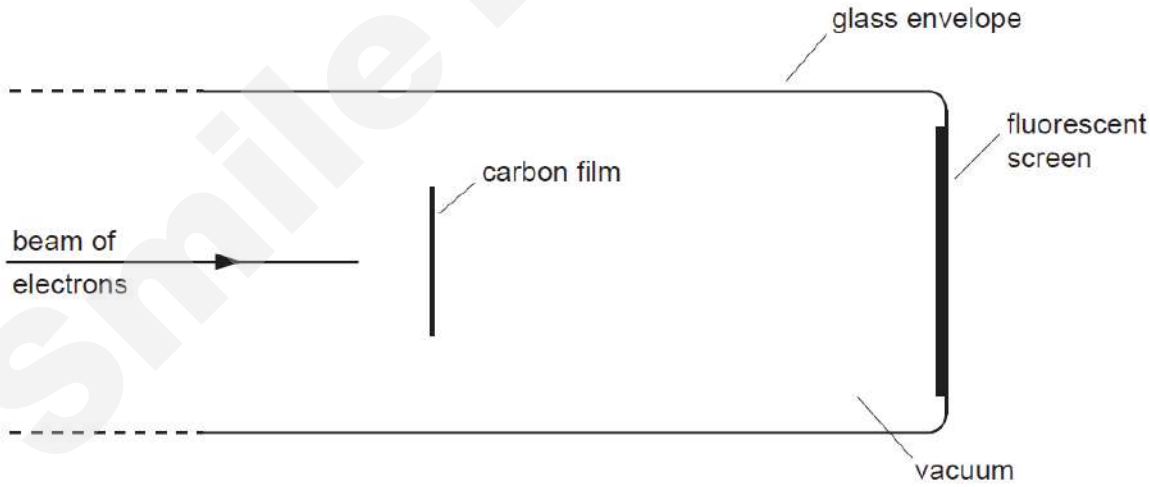

Fig. 6.1

(i) Assuming that the electrons behave as **particles**, predict what would be seen on the screen.

……

…… [1]

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(ii) In this experiment, the electrons do **not** behave as particles.

Describe briefly the pattern that is actually observed on the screen.

……

……

…… [2]

(b) The Heisenberg Uncertainty principle (HUP) for position and momentum can be written in the form

$$\Delta p \Delta x \geq h$$

where Δp is the uncertainty in momentum, Δx is the uncertainty in the position of a particle and h is the Planck constant.

(i) Calculate the uncertainty in momentum when an electron of mass 9.11×10^{-31} kg travelling at 3.00×10^{7} m s^{-1} passes through a narrow slit of width 1.00×10^{-10} m (comparable to the spacing of atoms in a crystal).

uncertainty in momentum = ... kg m s^{-1} [2]

(ii) Compare this uncertainty in momentum to the original momentum of the electron and state its significance.

……

……

……

…… [2]

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7 The article below is based on articles on the Internet.

Read the article and then answer the questions that follow.

Use of ultrasonic sound waves on biological cells

Ultrasonic sound waves (ultrasound) are produced and detected using an ultrasound transducer. Ultrasound transducers are capable of sending an ultrasound and then the same transducer can detect the sound and convert it to an electrical signal to be diagnosed.

To produce an ultrasound, a piezoelectric crystal has an alternating current running through it. The piezoelectric crystal grows and shrinks depending on the voltage applied across it. Running an alternating current through it causes it to vibrate at a high speed and to produce an ultrasound.

Ultrasound have frequencies outside the audible range of the human ear, that is, greater than about 20 kHz.

When an ultrasound passes through a medium, its wave energy is absorbed. The rate at which energy is absorbed by unit mass of the medium is known as the dose-rate. The dose-rate is measured in W kg^{-1}. The total energy absorbed by unit mass of the medium is known as absorbed dose. This is measured in J kg^{-1} or, as in this question, kJ kg^{-1}.

Under certain circumstances, biological cells may be destroyed by ultrasound. The effect on a group of cells is measured in terms of the survival fraction (*SF*).

$$SF = \frac{\text{number of cells surviving after exposure}}{\text{number of cells before exposure}}$$

For any particular absorbed dose, it is found that the survival fraction changes as the dose-rate increases. Fig. 7.1 shows the variation with dose-rate of the survival fraction for samples of cells in a liquid. The absorbed dose for each sample of cells was 240 kJ kg^{-1}.

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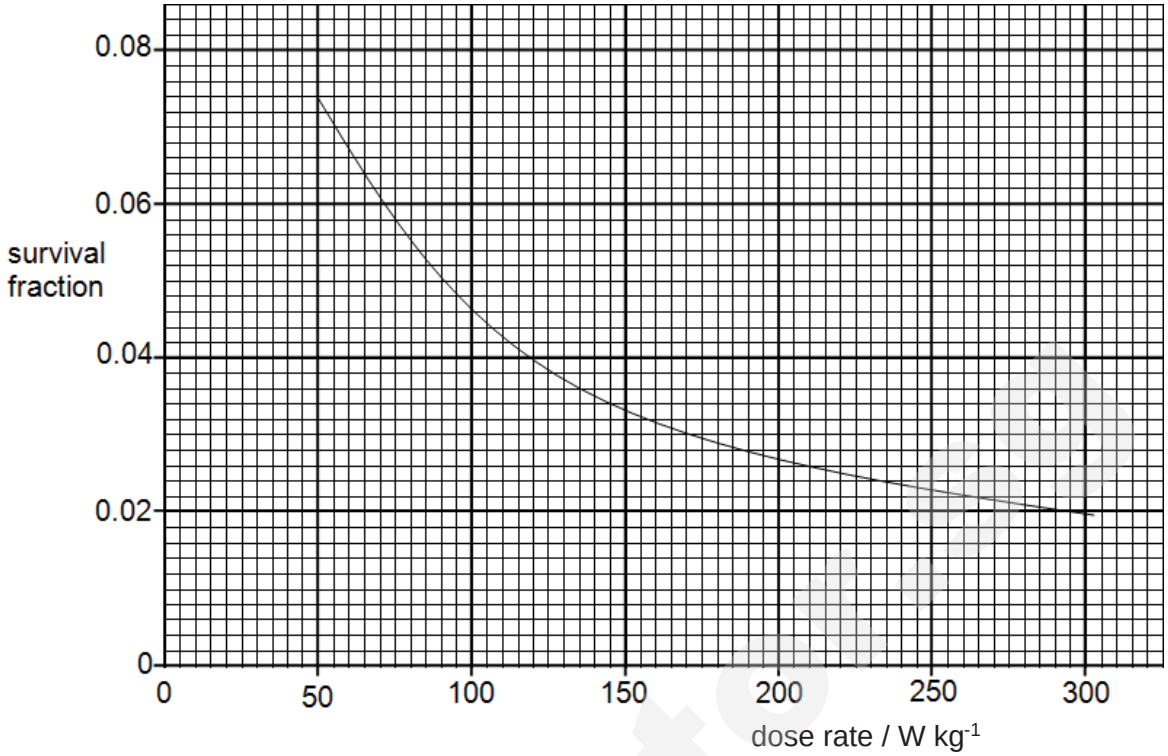

Fig. 7.1

(a) **(i)** State the transformation of energy that occurs in an ultrasound transducer.

……..... [1]

(ii) State one difference between ultrasound and light.

…….....

…….....

…….....

……..... [2]

(b) **(i)** Use Fig. 7.1 to state the survival fraction for a dose-rate of 200 W kg^{-1}.

survival fraction = ... [1]

(ii) Calculate the exposure time for an absorbed dose of 240 kJ kg^{-1} and at a dose-rate of 200 W kg^{-1}.

exposure time = …….... s [2]

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(c) Survival fraction depends not only on dose-rate but also on absorbed dose. Fig. 7.2 shows the variation with dose-rate of $\log_{10}(SF)$ for different values of absorbed dose.

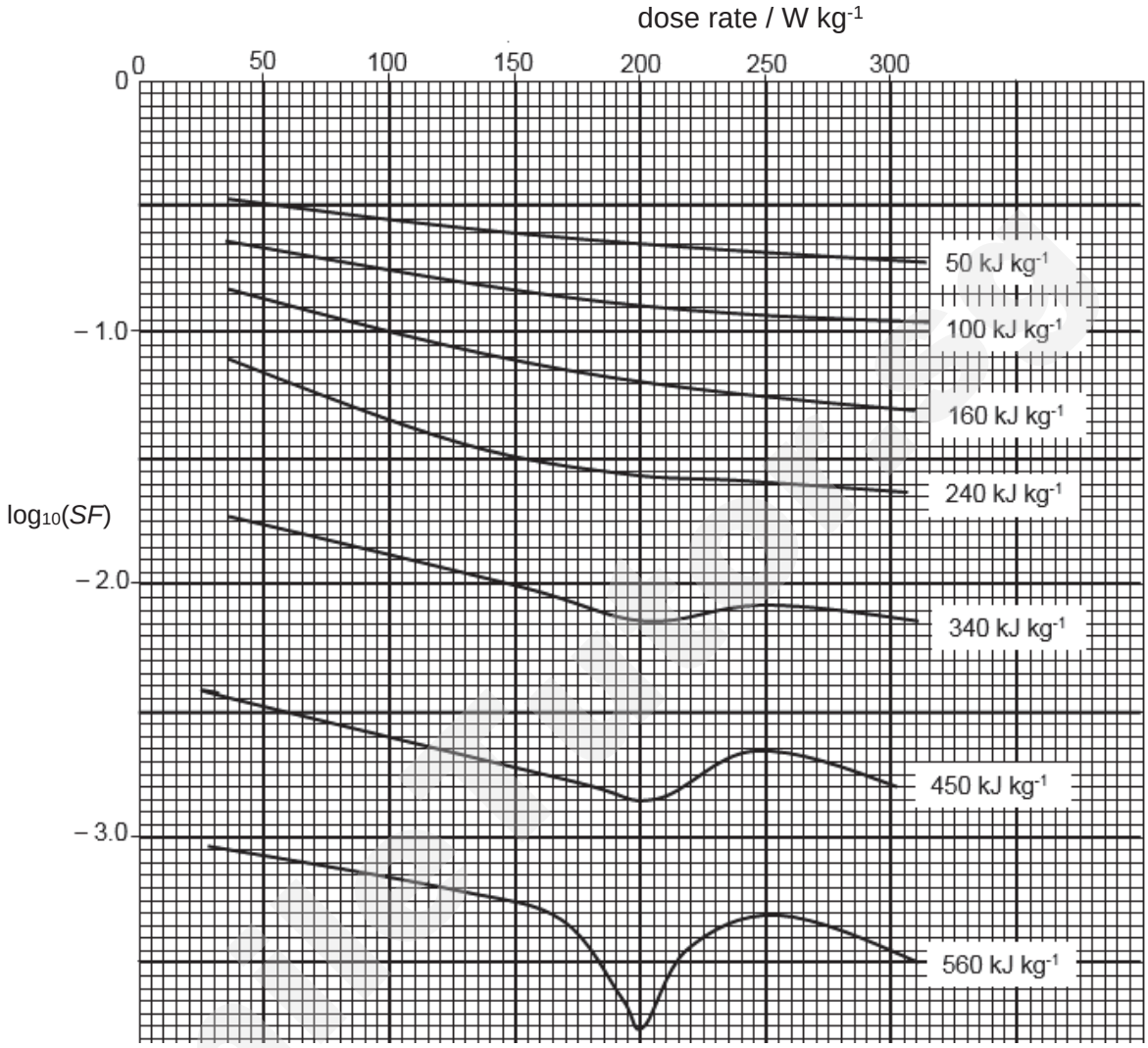

Fig. 7.2

The line with absorbed dose of 240 kJ kg^{-1} represents the data given in Fig. 7.1, but with survival fraction plotted on a logarithmic scale.

(i) Suggest why the survival fraction is plotted on a logarithmic scale.

……

…… [1]

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(ii) Use Fig. 7.2 to complete the table of Fig. 7.3 for a dose-rate of 200 W kg^{-1}.

absorbed dose / kJ kg^{-1}	$\log_{10}(SF)$
50	
100	
160	
240	
340	
450	
560	

Fig. 7.3

[3]

(iii) Use Fig. 7.3 to calculate the survival fraction for an absorbed dose of 160 kJ kg^{-1} at a dose-rate of 200 W kg^{-1}.

SF = ... [1]

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(d) Use the table of Fig. 7.3 to plot, on the axes of Fig. 7.4, a graph to show how the variation with absorbed dose of $\log_{10}(SF)$ for the dose-rate of 200 W kg^{-1}. [3]

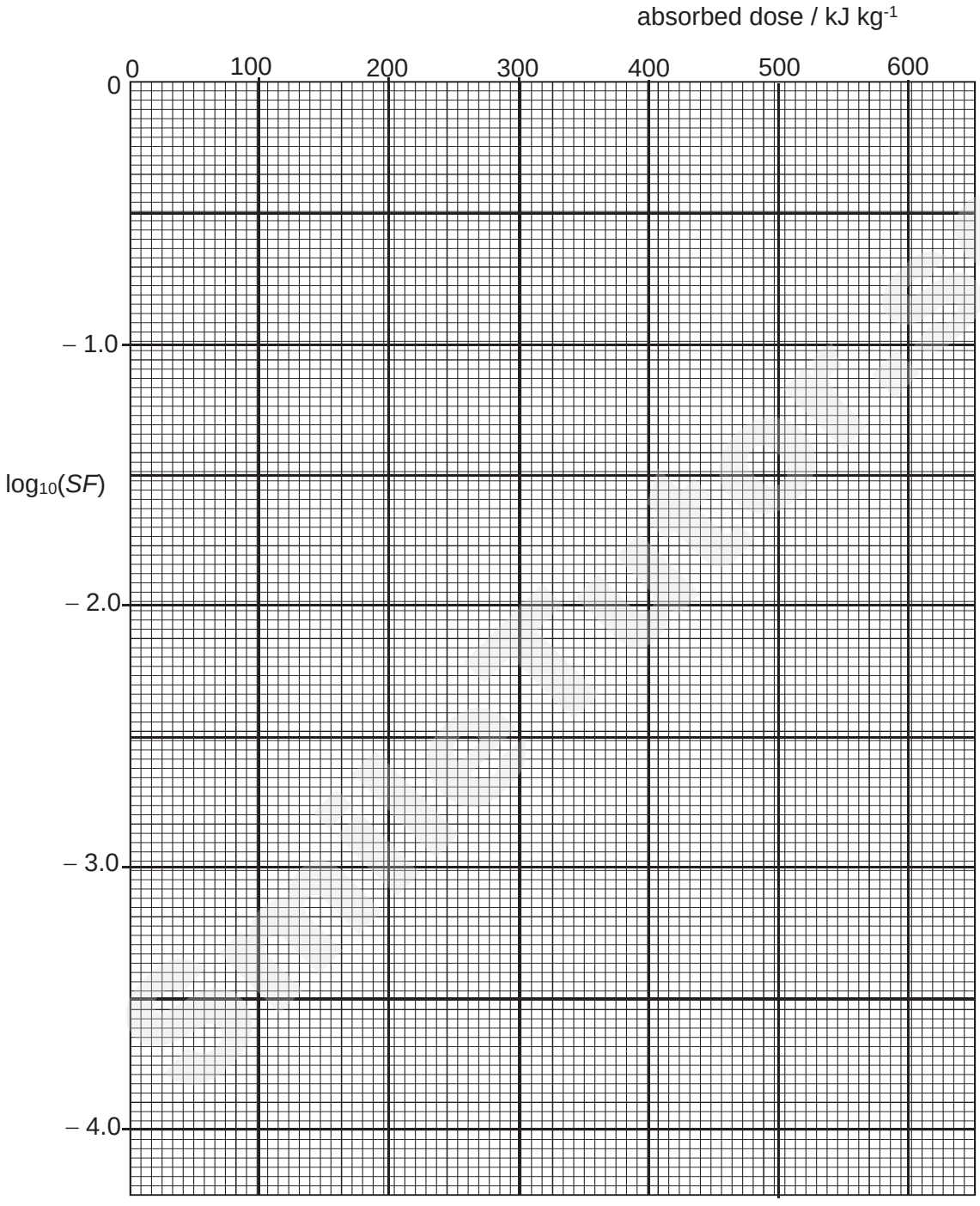

Fig. 7.4

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(e) Theory suggests that at a dose-rate of 200 W kg^{-1}, two separate effects may give rise to cell destruction. According to this theory, one of the effects becomes apparent only at higher absorbed doses. State the evidence provided for this theory by

(i) Fig. 7.2,

……

……[1]

(ii) Fig 7.4.

……

…… [2]

(f) The theory outlined in **(e)** suggests that the resultant survival fraction $(SF)_R$ due to two independent effects which have survival fractions $(SF)_1$ and $(SF)_2$ is given by the expression

$$(SF)_R = (SF)_1 \times (SF)_2$$

(i) Suggest how the graph in Fig. 7.4 may be used to determine $(SF)_R$ for an absorbed dose of 560 kJ kg^{-1}.

……

……

…… [1]

(ii) With reference to the graph in Fig. 7.4, discuss how it is possible to determine separate values of $(SF)_1$ and $(SF)_2$ for the absorbed dose of 560 kJ kg^{-1}.

……

……

……

……

……

…… [3]

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ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS Higher 2
9749/03

Paper 3 Longer Structured Questions **Thursday 14 September 2017**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Significant Figure	
Total (80 marks)	

This document consists of **21** printed pages and **1** blank page.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{x_o^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section.

1 Fig. 1.1 shows a trolley of mass 0.80 kg, on a bench surface, connected to a mass *M* by a string. The mass *M* is released and the trolley moves along the surface. Fig. 1.2 shows the variation of the velocity *v* of the trolley with time *t* for the motion from A to B.

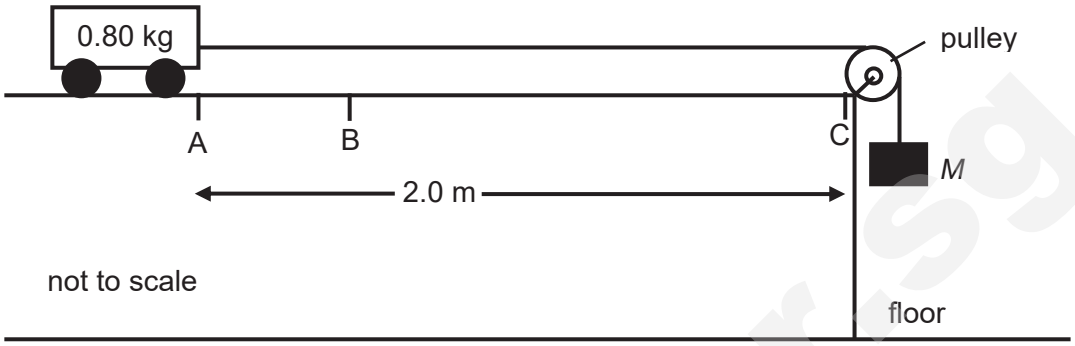

Fig. 1.1

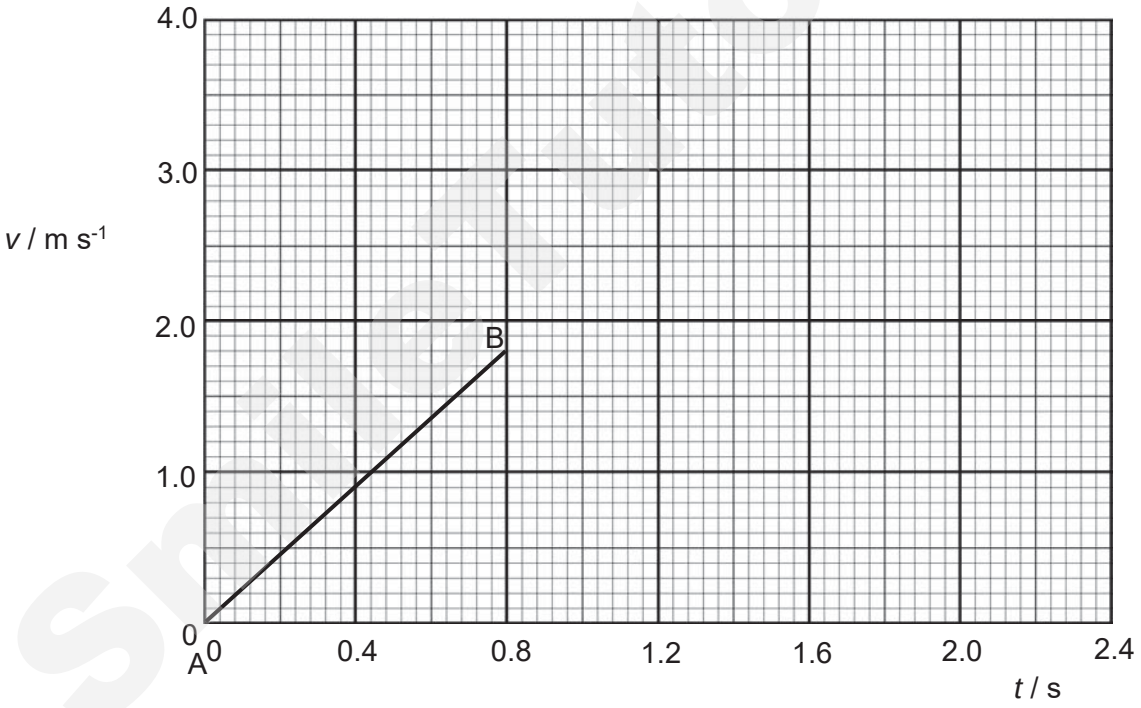

Fig. 1.2

(a) Calculate the acceleration of the trolley between A and B.

acceleration = ……m s^{-2} [1]

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(b) Show that the distance from A to B is 0.72 m.

[1]

(c) When the trolley reaches B the mass *M* has just reached the floor.

(i) Ignoring any resistive forces, calculate the time it takes the trolley to travel from B to C.

time = ……..s [2]

(ii) On Fig. 1.1, complete the graph for the trolley moving from B and coming to rest at the pulley at C. [2]

(iii) Using energy considerations, determine the mass *M*.

M = ……..kg [2]

2 Bodies A and B of mass *2M* each are located at a distance *D* from one other as shown in Fig. 2.1.

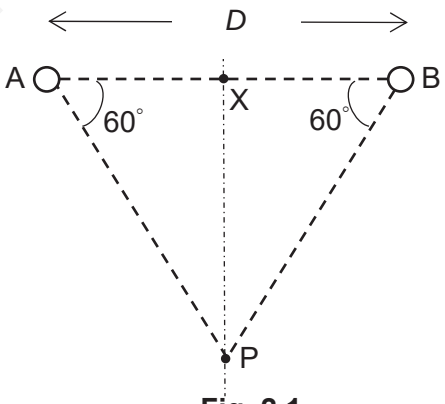

Fig. 2.1

(a) **(i)** Determine the net gravitational potential ϕ_p at P, in terms of *M, D* and the gravitational constant *G*, due to masses A and B.

ϕ_p = …….. [2]

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(ii) A stationary mass m is released at P and it moves to point X under the influence of gravitational field by A and B. Determine the speed of the mass, v_x, when it reaches X in terms of m, G, M and D.

v_x = …….. [2]

(b) Electrical charges of $+2Q$ and $-Q$ were induced in bodies A and B respectively and it was assumed that the electrical charges were evenly distributed on the surfaces of A and B.

Taking direction towards B as positive, sketch on the axes provided below,

(i) the variation with distance from A of the gravitational field strength and gravitational potential between AB.

Label your graphs g for gravitational field strength and ϕ for gravitational potential respectively.

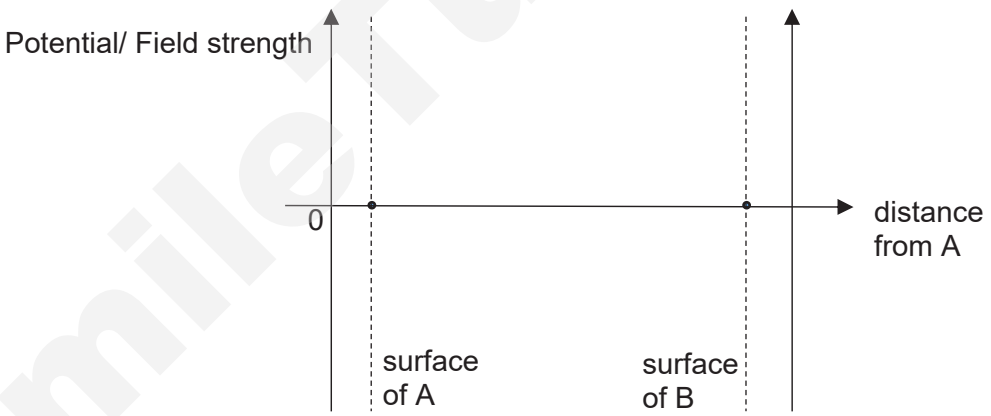

Fig 2.2

[2]

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(ii) the variation with distance from A of the electric field strength and electric potential between AB.

Label your graphs *E* for electric field strength and *V* for electric potential respectively.

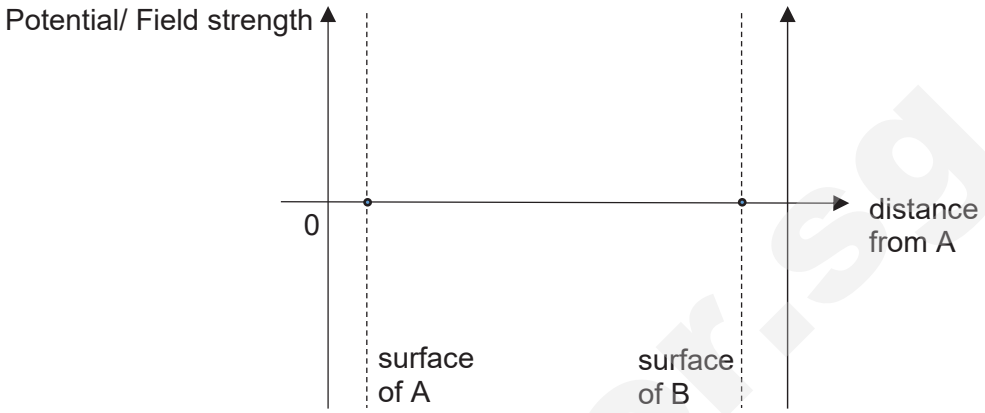

Fig 2.3

[2]

(iii) At point R in Fig 2.4 below, a body of mass *M* and charge +*Q* is being released from rest.

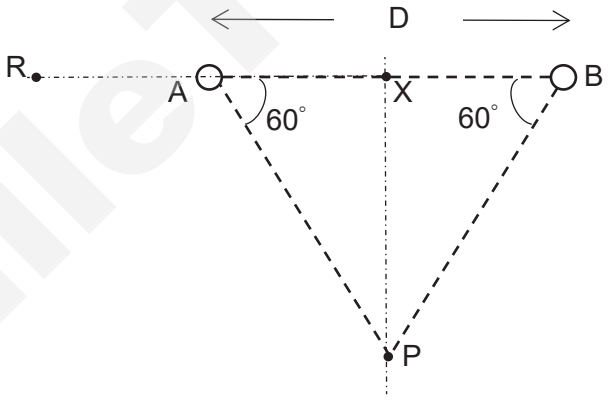

Fig 2.4

Suggest with a reason the direction of the body's subsequent motion.

……

……

……[2]

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3 In a heat engine, the working substance is an ideal monatomic gas with 3.0 moles of molecules. The gas undergoes a cycle of thermodynamic processes ABCDA as it drives the engine as shown in Fig 3.1.

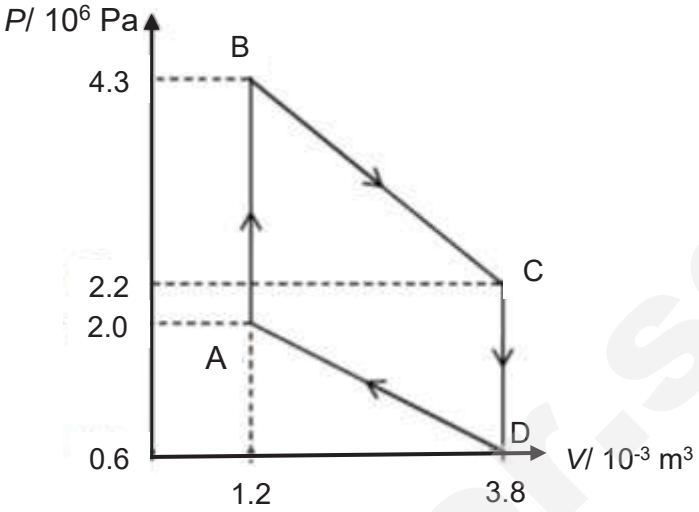

Fig 3.1

(a) Determine the thermodynamic temperature of the gas at B.

temperature = ... K [2]

(b) Determine the change in internal energy of the gas in process BC.

change in internal energy = ... J [2]

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(c) Determine the work done by the gas in process BC.

work done by gas = ……... J [2]

(d) Determine the heat absorbed by the gas in process BC.

heat absorbed = ……... J [2]

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4 **(a)** Light is an example of transverse electromagnetic wave.

Light can be polarized. Explain how this gives evidence for light being a transverse wave.

……..

…….....[1]

(b) Fig. 4.1 shows an ideal polarizer A arranged so that its polarizing direction is vertical. Polariser B is oriented with its plane parallel to that of A and with its polarizing direction at 45° to the vertical.

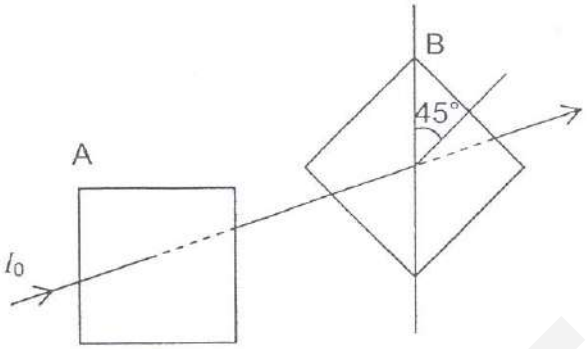

Fig. 4.1 a

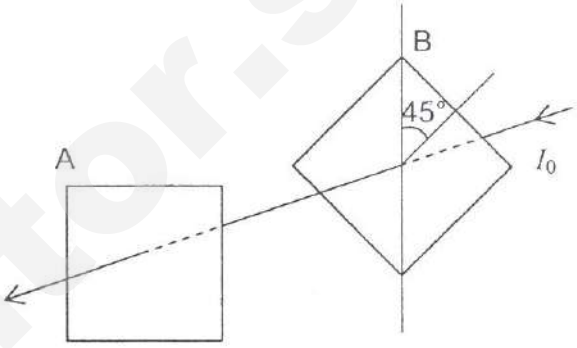

Fig. 4.1b

A beam of vertically-polarised light, of initial intensity I_o, passes through the polarisers in turn. Determine the intensity and the orientation of the emergent beam when the beam passes through the polarizer system

(i) in the direction from A to B (Fig. 4.1a),

intensity = …….

orientation =…….
[3]

(ii) in the direction from B to A (Fig. 4.1b).

intensity = …….

orientation = …….
[2]

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5 **(a)** State what is meant by the *diffraction* of a wave.

……..

……[1]

(b) Two identical point sources of monochromatic light of wavelength 600 nm are placed at a distance of 40 m from a slit and at a separation of 10 mm, as shown in Fig 5.1. The images of the point sources of monochromatic light are formed on a screen situated 25 mm away from the slit.

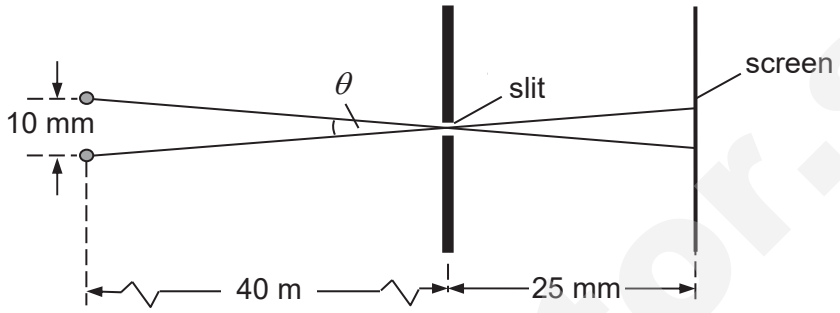

Fig. 5.1

(i) Calculate the angle subtended θ at the slit by the two sources.

θ = ……rad [1]

(ii) If the slit has a width of 1.5 mm, discuss whether or not the two images will be resolved.

……

……

……[3]

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(c) An arrangement for demonstrating the interference of light is shown in Fig. 5.2.

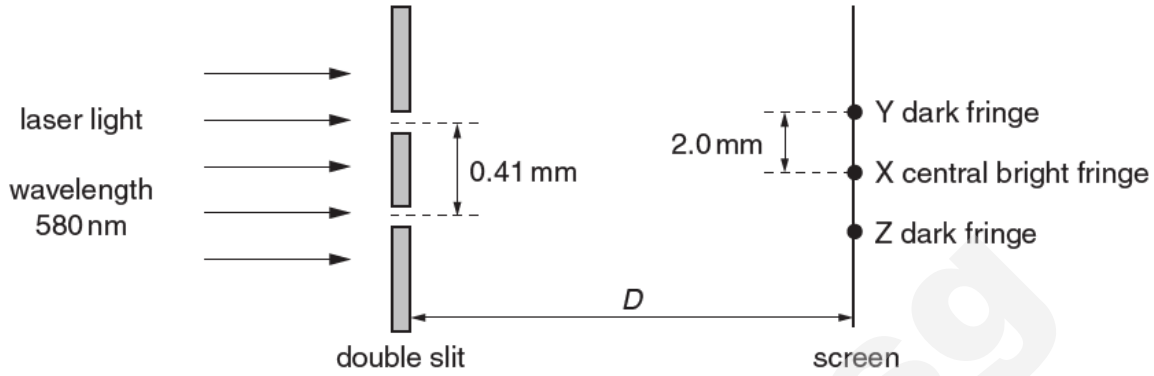

Fig. 5.2 (not to scale)

The wavelength of the light from the laser is 580 nm. The separation of the slits is 0.41 mm. The perpendicular distance between the double slit and the screen is *D*.

Coherent light emerges from the slits and an interference pattern is observed on the screen. The central bright fringe is produced at point X. The closest dark fringes to point X are produced at points Y and Z. The distance XY is 2.0 mm.

(i) Explain why a bright fringe is produced at point X.

……

……

……

…… [2]

(ii) State the difference in the distances, in nm, from each slit to point Y.

distance = …… nm [1]

(iii) Calculate the distance *D*.

D = …… m [2]

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6 A long, straight wire Z carrying a direct current of 2.0 A flows in the direction as shown in Fig. 6.1.

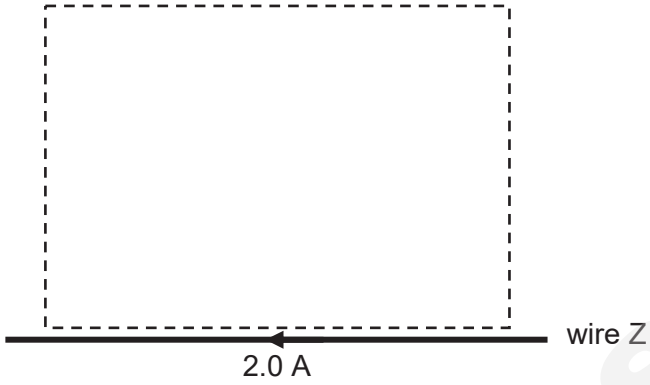

Fig. 6.1

(a) Using symbols X or ⊙ to represent the direction of magnetic field into or out of the paper respectively, draw on Fig. 6.1 the pattern of magnetic field produced by wire Z in the region indicated by the dotted box.

[2]

(b) A positive ion is projected from point P with an initial velocity *v* in a direction perpendicular to wire Z as shown in Fig. 6.2.

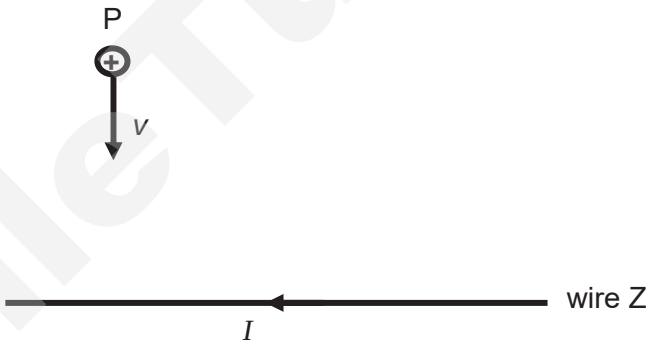

Fig. 6.2

Describe and explain the subsequent path of the ion, shortly after leaving P, due to the effect of the wire's magnetic field.

……..

……..

……..

……..

…….....[3]

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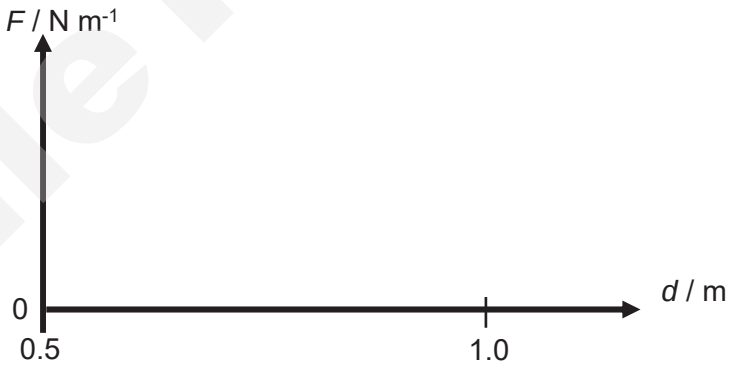
(c) A similar wire Y is placed parallel to wire Z. The separation *d* between the two wires is 1.0 m. Wire Y is carrying a current of 1.0 A in the same direction as wire Z.

(i) Calculate the resultant magnetic flux density at the mid-point between the two wires.

magnetic flux density = ……T [2]

(ii) Wire Y moves towards wire Z such that the separation *d* of the two wires decreases from 1.0 m to 0.5 m. Wire Y is maintained parallel to wire Z throughout the motion. Sketch the variation with separation *d* of the force per unit length *F* experienced by wire Y due to the magnetic field of wire Z.



[2]

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7 A π^0 meson is a sub-atomic particle.
A stationary π^0 meson, which has mass 2.4×10^{-28} kg, decays to form two γ-ray photons.
The nuclear equation for this decay is

$$\pi^0 \rightarrow \gamma + \gamma.$$

(a) Explain why the two γ-ray photons will move off in opposite directions with equal energies.

……..

……..

……..

……..

……..

…….....[3]

(b) Determine, for each γ-ray photon,

(i) the energy,

energy = ... J [2]

(ii) the wavelength,

wavelength = ... m [2]

(iii) the momentum.

momentum = ... N s [2]

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Section B

Answer **one** question in this section.

8 **(a)** Define

(i) resistance

……

…… [1]

(ii) the ohm

……

…… [1]

(b) Sketch the *I*–*V* characteristics of a metallic conductor at constant temperature on Fig. 8.1 and a filament lamp on Fig. 8.2. [2]

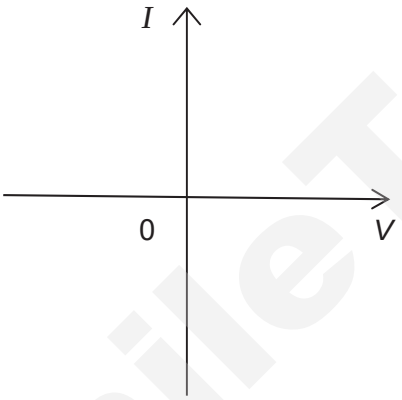

Fig. 8.1

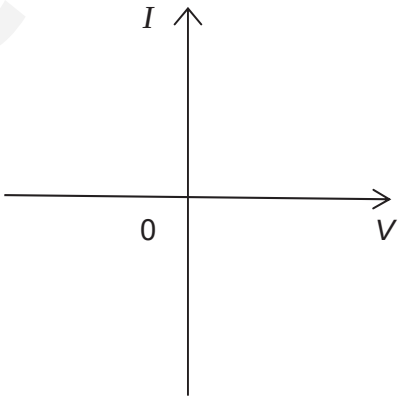

Fig. 8.2

(c) State and explain the difference between how the resistance of a filament lamp and the resistance of a semiconductor vary with temperature.

……

……

……

……

……

…… [3]

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(d) A copper wire of diameter 1.4 mm connects to the tungsten filament wire of a light bulb of diameter 0.020 mm. A current of 0.42 A flows through both of the wires. Copper has 8.0×10^{28} electrons per cubic metre and tungsten can be assumed to have 3.4×10^{28} electrons per cubic metre.

(i) The filament is 2.0 m long when uncoiled and has a resistivity of $5.5 \times 10^{-8}\ \Omega$ m.

Calculate the power dissipated in the filament bulb.

power dissipated = ……W [2]

(ii) The drift speed of electrons in the copper wire is 0.021×10^{-3} m s^{-1}.

1. Determine the drift speed of electrons in the tungsten filament.

drift speed = ……m s^{-1} [2]

2. Explain, in microscopic terms, why the copper wire stays cool although the tungsten filament reaches a high temperature.

……

……

……

……

……

……... [3]

(iii) State one important property of a conductor used to make heating elements.

……... [1]

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(e) A thermistor has resistance 3900 Ω at 0 °C and resistance 1250 Ω at 30 °C. The thermistor is connected into the circuit of Fig. 8.3 in order to monitor temperature changes.

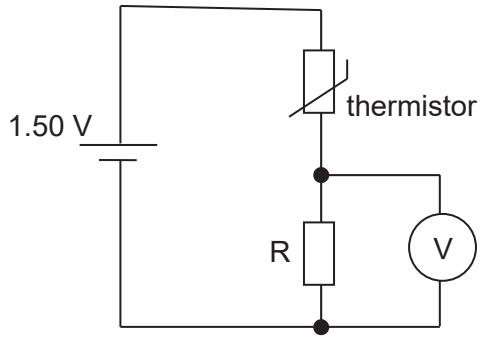

Fig. 8.3

The battery of e.m.f. 1.50 V has negligible resistance and the voltmeter has infinite resistance.

(i) The voltmeter is to read 1.00 V at 0 °C. Show that the resistance of resistor R is 7800 Ω.

[1]

(ii) The temperature of the thermistor is increased to 30 °C. Determine the reading on the voltmeter.

reading = ……V [2]

(iii) The voltmeter in Fig. 8.3 is replaced with one having a resistance of 7800 Ω. Calculate the reading on this voltmeter for the thermistor at a temperature of 0 °C.

reading = ……V [2]

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9 **(a)** State and explain two relations in which the Planck constant h is the constant of proportionality.

1. ……

……

……

……

2. ……

……

……

……[4]

(b) Experiments are conducted to investigate the photoelectric effect.

(i) It is found that, on exposure of a metal surface to light, either electrons are emitted immediately or they are not emitted at all.

Suggest why this observation does not support a wave theory of light.

……

……

……

……[3]

(ii) Data for the wavelength λ of the radiation incident on the metal surface and the maximum kinetic energy E_k of the emitted electrons are shown in Fig. 9.1.

λ /nm	E_k /10^{-19} J
650	-
240	4.44

Fig. 9.1

1. Without any calculation, suggest why no value is given for E_k for radiation of wavelength 650 nm.

……

……[1]

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2. Use data from Fig. 9.1 to determine the work function energy of the surface.

work function energy = ... J [2]

(iii) Radiation of wavelength 240 nm gives rise to a maximum photoelectric current I. The intensity of the incident radiation is maintained constant and the wavelength is now reduced.

State and explain the effect of this change on

1. the maximum kinetic energy of the photoelectrons,

.....

.....

..... [2]

2. the maximum photoelectric current I.

.....

.....

..... [2]

(c) Some electron energy levels in atomic hydrogen are illustrated in Fig. 9.2.

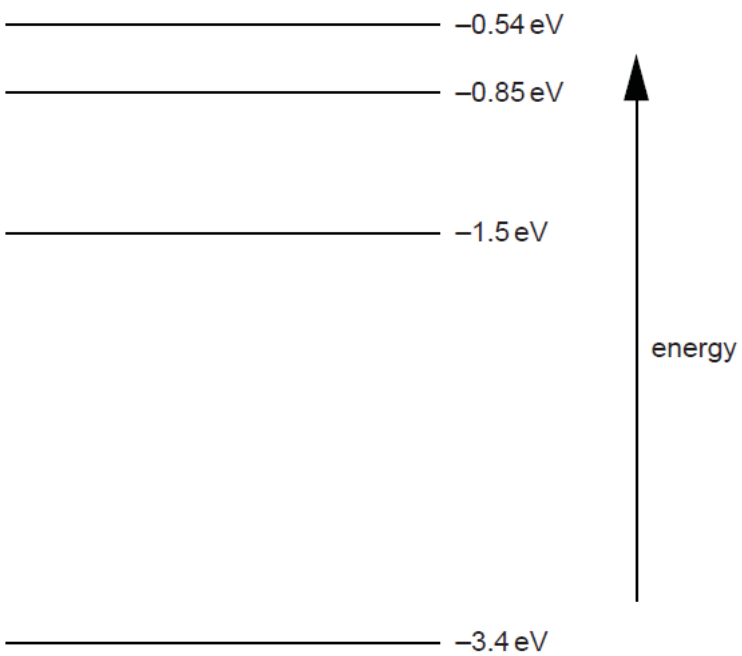

Fig. 9.2

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The longest wavelength produced as a result of electron transitions between two of the energy levels shown in Fig. 9.2 is 4.0×10^{-6} m.

(i) On Fig. 9.2,

1. draw, and mark with the letter L, the transition giving rise to the wavelength of 4.0×10^{-6} m, [1]

2. draw, and mark with the letter S, the transition giving rise to the shortest wavelength. [1]

(ii) Calculate the wavelength for the transition you have shown in **(i) part 2**.

wavelength = ……m [2]

(iii) Photon energies in the visible spectrum vary between approximately 3.66 eV and 1.83 eV.

Determine the energies, in eV, of photons in the visible spectrum that are produced by transitions between the energy levels shown in Fig. 9.2.

photon energies = ……eV [2]

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ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS Higher 2 9749/04

Paper 4 Practical **Friday 25 August 2017**

2 hours 30 minutes

Candidates answer on the Question Paper.
Additional Materials: As listed on the Confidential Instructions

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READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose mark if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

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Paper 4 (55 marks)	
1	
2	
3	
4	
Total (55 marks)	

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1 In this experiment, you will investigate how the period of torsional oscillations of a bar magnet suspended above a fixed bar magnet changes with the separation between the two magnets.

(a) **(i)** Fix one of the magnets to the bench top using Blu-tack.

(ii) Suspend a second magnet using a stirrup and thread so that it lies in a horizontal plane about 50 cm below the point of suspension. The distance *d* between the bottom of the suspended magnet and the top of the fixed magnet should initially be about 5 cm. The base of the stand should be as far as possible from the fixed bar magnet. The arrangement is shown in Fig. 1.1.

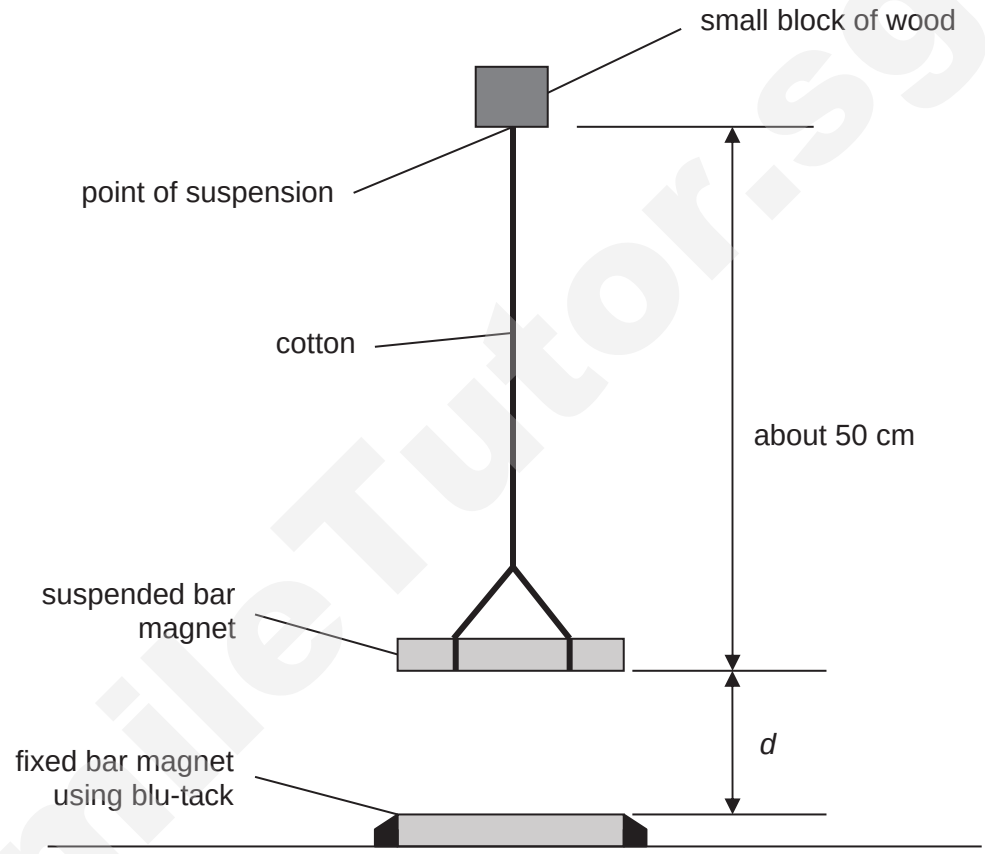

Fig. 1.1

(b) **(i)** Measure and record distance *d*.

d = ... [1] M1

(ii) Estimate the percentage uncertainty in *d*, showing your working.

percentage uncertainty =..... [1] A1

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(iii) Gently rotate the suspended magnet and release it so that it performs small torsional oscillations in a horizontal plane, as shown in Fig. 1.2.

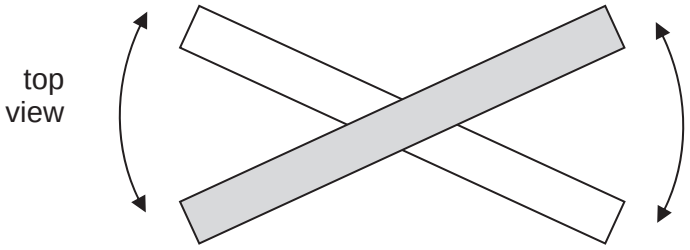

Fig.1.2

Make and record measurements to determine the period T of these oscillations.

M2	
A2	

T = ... [2]

(c) It is suggested that period T is proportional to separation d.

Change d to a value between 3 cm to 10 cm and take another set of measurements to investigate this suggestion.
State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

M3	
A3	
A4	
A5	
A6	

.....

.....

.....

.....

.....

..... [5]

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(d) Explain why, in practice, it may be difficult to measure the period T directly for a separation d = 1 cm.

……

…… [1]

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A7	

(e) A student suggests that the period of torsional oscillations T depends on the mass distribution of the oscillating body about its axis of rotation.

Suggest changes that could be made to the setup in Fig. 1.1 to study the student's claim when two lumps of plasticine of equal mass are provided.

……

……

……

……

……

…… [3]

PL1	
PL2	
PL3	

[Total: 13 marks]

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2 This investigation considers how the force required to maintain equilibrium of a horizontal rule depends on the position of a mass suspended from the rule.

(a) **(i)** Suspend a metre rule horizontally using two loops of string and a newton-meter, as shown in Fig. 2.1. The strings must be vertical.

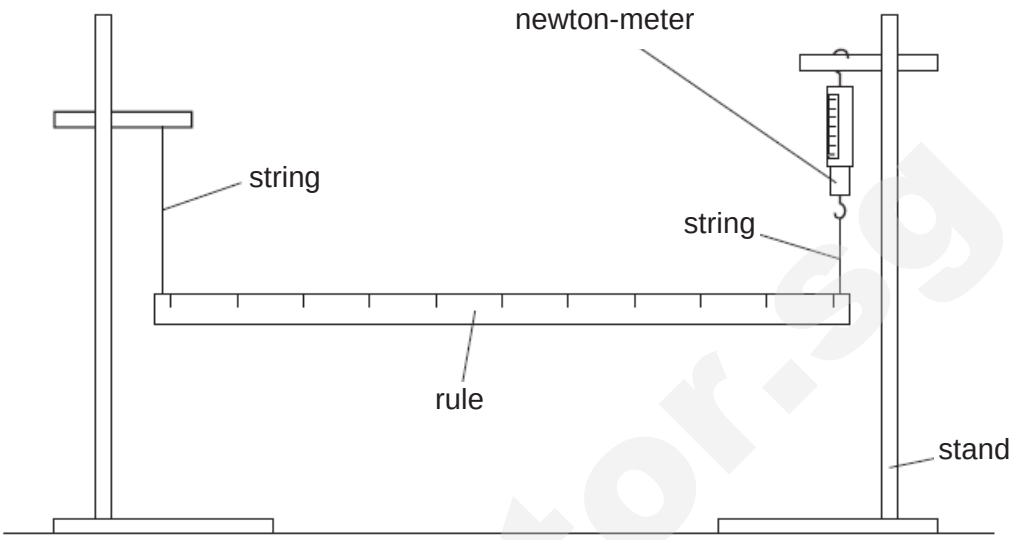

Fig. 2.1

(ii) Suspend the 50 g mass at a distance *d* from the newton-meter using a loop of string. You will need to adjust the position of the clamps to ensure that the rule remains horizontal. The arrangement should now be as shown in Fig. 2.2.

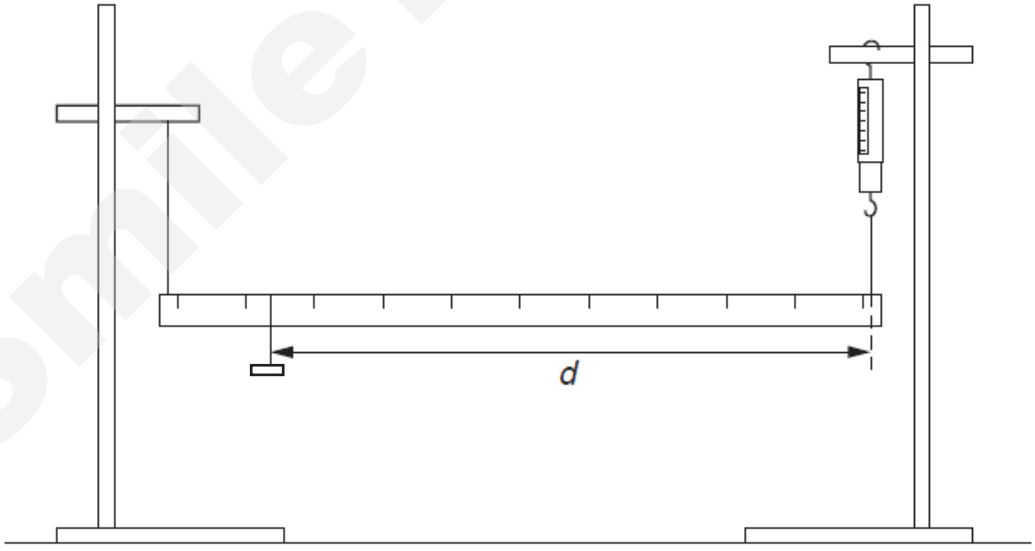

Fig. 2.2

(b) **(i)** Measure and record the value of *d* and the reading *F* from the newton-meter.

d =……

F =……[1]

M1

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(ii) Slide the suspended mass to a new position on the rule and repeat **(b)(i)**. Record at least five more readings of d and F. You should ensure when you are taking readings that the rule is horizontal and that the newton-meter does not go off scale.

M2
M3
M4

[3]

(iii) Explain how you ensured that the rule was horizontal when the measurements were taken.

……

……

……[1]

A1

(c) Plot your values from **(b)(ii)** on Fig. 2.3.

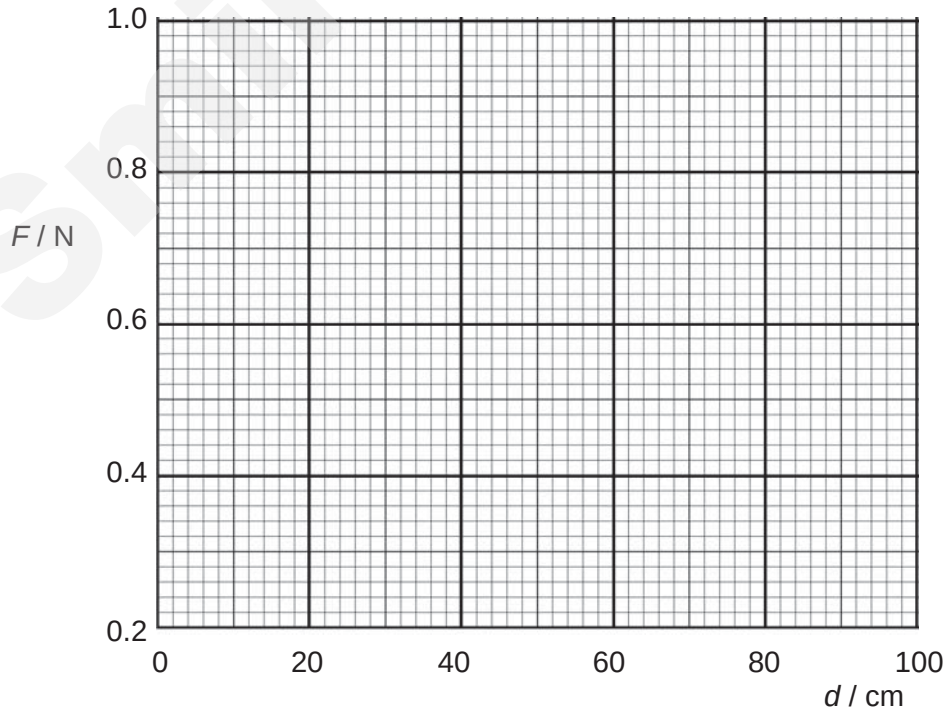

Fig. 2.3

P1
P2

[2]

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(d) The equation that relates F and d is

$$F = \frac{-Wd}{L} + \frac{mg}{2} + W$$

where W is the weight of the suspended mass, m is the mass of the rule, L = 0.980 m, and g = 9.81 m s^{-2}.

Use your graph of Fig. 2.3 to determine value for m. Include appropriate unit.

A2	
A3	
A4	

m =……[3]

[Total: 10 marks]

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3 In this experiment, you will determine the resistivity of a metal in the form of a wire.

(a) **(i)** Measure and record the diameter d of the wire attached to the metre rule.

d = ... [1] M1

(ii) Calculate the cross-sectional area A of the wire.

A =.....m^2 [1] A1

(b) **(i)** Use the wire attached to the metre rule, one of the voltmeters and one of the two identical resistors of resistance R to set up the partial circuit shown in Fig. 3.1.
The value of R is 10 Ω.

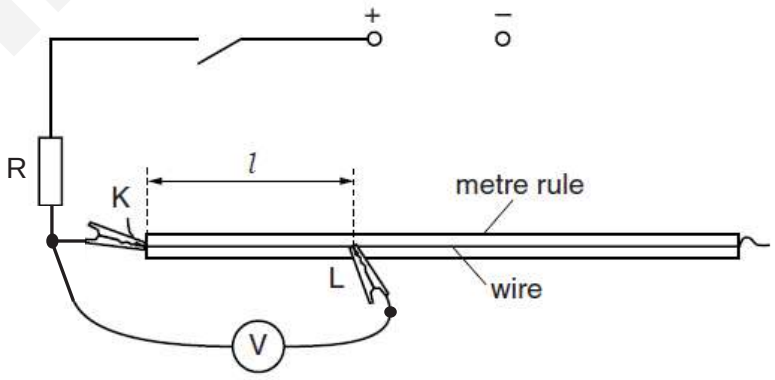

Fig. 3.1

There are two crocodile clips, one labelled K and the other labelled L.
Place K and L so that the distance l between them is approximately 30 cm.

(ii) Measure and record the distance l between K and L.

l = ...

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(iii) Use the other resistor and the other voltmeter to complete the circuit shown in Fig. 3.2.

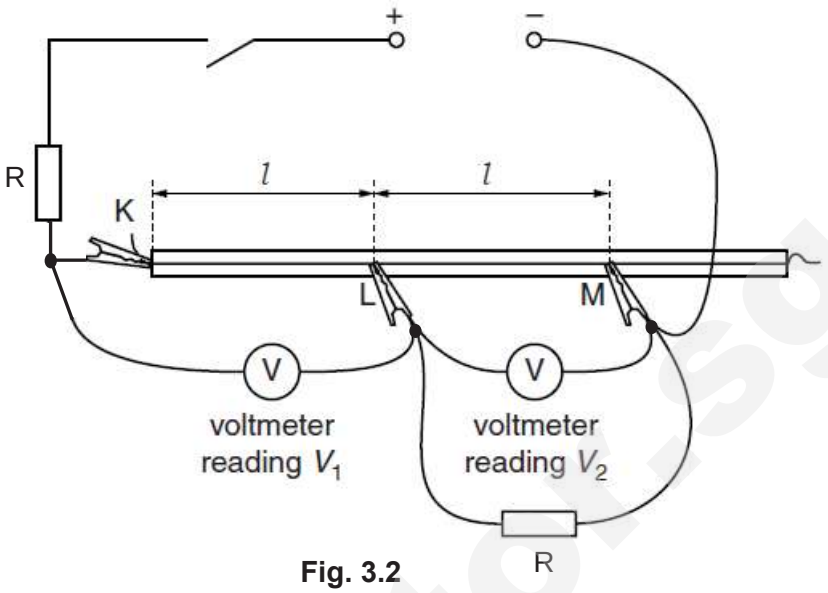

Fig. 3.2

(iv) Place the crocodile clip M at a distance l from L.
The value of l should be the same as in **(b)(ii)**.

(c) **(i)** Switch on the power supply.

(ii) Record the voltmeter readings V_1 and V_2 as shown in Fig. 3.2.

V_1 = ... V

V_2 = ... V

(iii) Switch off the power supply.

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(d) Change l and repeat **(b)(ii)**, **(b)(iv)** and **(c)** for further sets of readings of l, V_1 and V_2. For each set of readings, distances KL and LM should **both** be l.

M2	
M3	
P1	
P2	
P3	
A2	

[7]

(e) Theory suggests that V_1, V_2 and l are related by the expression

$$\frac{V_1}{V_2} = P\,l + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.

A3	
A4	
A5	

P = ……

Q = …… [3]

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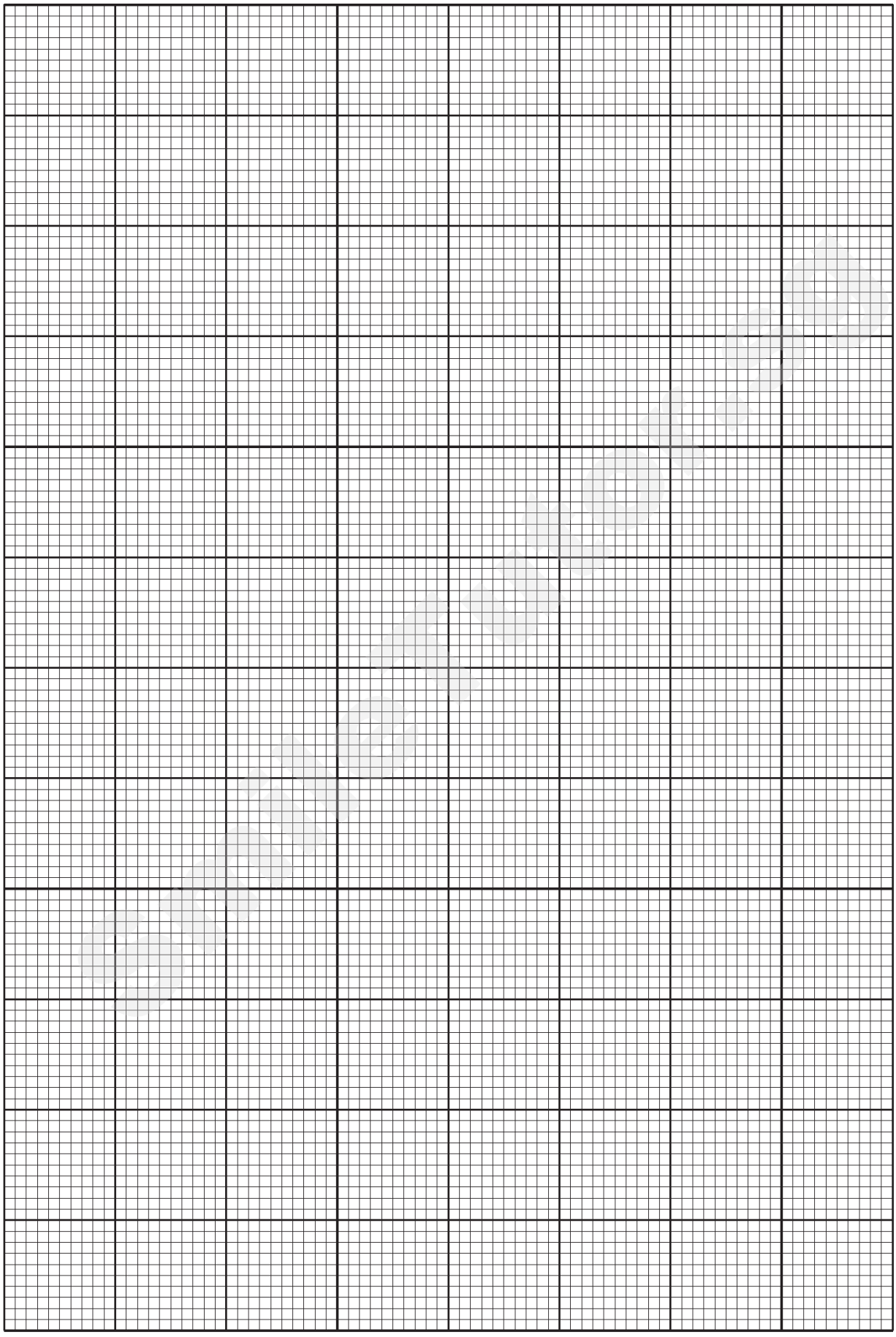

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P4	
P5	
P6	
A7	

[3]

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(f) Comment on any anomalous data or results you may have obtained.
Explain your answer.

……

……

……[1] M4

(g) The quantity P is given by the expression

$$P = \frac{\rho}{AR}$$

where ρ is the resistivity of the material of the wire.

(i) Use values from **(a)(ii)**, **b(i)** and **(e)** to find a value for ρ.

ρ = …… [1] A6

(ii) In the expression $\frac{V_1}{V_2} = P\,l + Q$, Q is independent of R.

The experiment is repeated with a smaller value of R.

On the graph grid on page 11, sketch a second graph to represent the new results. Label it Z. [1]

(h) **(i)** State one significant source of error.

……

……

……[1] A8

(ii) Suggest one improvement that could be made to the experiment to address the source of error identified in **(h)(i)**. You may suggest the use of other apparatus or a different procedure.

……

……

……[1] A9

[Total: 20 marks]

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Please turn over for question 4.

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4 A student is interested in 'bungee jumping', where a person attached to an elastic cord falls from a height and travels downwards through a distance before moving upwards. Different cords are used for different people. A schematic diagram is shown in Fig. 4.1.

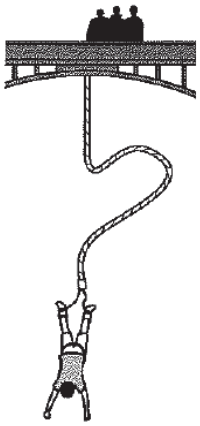

Fig 4.1

The student models 'bungee jumping' in the laboratory by using elastic cords of unstretched length 50.0 cm with different spring constants. An object is attached to each cord.
The student investigates the relationship between the maximum distance h fallen by the object and the spring constant k of the elastic cord.

It is suggested that the relationship between h and k is

$$\frac{1}{2}k(h - L)^2 = mgh$$

where L is the unstretched length of the cord, m is the mass of the object and g is the acceleration of free fall.

Design a laboratory experiment to test the relationship between h and k.

Explain how your results could be used to plot a graph with $\frac{(h-L)^2}{h}$ on the y-axis and to determine the value of g. You should draw a labelled diagram to show the arrangement of your apparatus.

In your account you should pay particular attention to

(a) the procedure to be followed,
(b) the measurements to be taken,
(c) the control of variables,
(d) the analysis of the data,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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[12]

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2017 AJC JC2 H2 Physics Prelim Solutions
Paper 1 (30 marks)

Answer

1	2	3	4	5	6	7	8	9	10
D	A	B	B	C	D	B	D	C	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A	C	B	D	A	C	C	C	A	C
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
A	D	A	C	A	D	B	B	B	A

No	Answer & Solution
1	**Ans: D** 2000 pV = 2000 x 10^{-12} V = 2 x 10^{-9} V = 2 x 10^{-15} x 10^{6} V = 2 x 10^{-15} x M V p.d. = work done per unit charge, hence V is equivalent to J C^{-1}
2	**Ans : A** For the projectile motion, horizontal speed is constant, *v*. Vertical speed is zero initially and acceleration is *g*, downwards. Let the height of the table be *h*. Using s = ut + ½ at^2 $h = 0 + \frac{1}{2} g T^2$ $T = \sqrt{\frac{2h}{g}}$ *T* is independent of mass. Range, *D* = *vT*. Since both *v and T* are independent of mass, *D* will remain the same.
3	**Ans : B** The scale reads the contact force between the sack and scale. Since the scale reading is larger than the mass, the upward contact force must be larger than the downward weight. The sack experiences a net force and acceleration upwards. (12 – 10) x 9.81 = 10 x acceleration acceleration = 1.962 ≈ 2.0 m s^{-2}.
4	**Ans : B** For elastic collision, total KE is conserved OR relative speed of approach equals to relative speed of separation. Total KE before impact = ½ mv^2 + ½ mv^2 = mv^2 Thus, total KE after impact = mv^2. Answer C is wrong because during collision, KE is not conserved. It is converted to elastic PE then back to KE. Answer D is wrong because total momentum before impact = mv + m(-v) = 0

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	Answer A is wrong because when the spheres stick together, it is already a perfectly inelastic collision. Also note that relative speed of approach = $u_1 - u_2 = v - (-v) = 2v$ (non-zero). If the spheres stick together, they will share the same speed and relative speed of separation will be zero.
5	**Ans : C** Work done is minimum if the force applied is just enough to overcome the barrel's weight on its way up the plank, with no change in speed. The barrel gains GPE without any gain in KE. Minimum work = Gain in GPE = mgh = 50 x 9.81 x 1.6 = 784.8 J ≈ 780 J Alternative method : Work done = Force x distance = mg sin θ x d = 50 x 9.81 x (1.6/3.4) x 3.4 = 784. 8 J
6	**Ans: D** Upthrust = weight of air displaced (smallest force as density of air is very small). Viscous drag is proportional to speed which increases as ball falls. At terminal speed, downward weight of ball is a constant which is balanced by upward drag and upthrust. Hence, weight > viscous drag > upthrust.
7	**Ans: B** For equilibrium, all three forces must meet at a common point, which is a point below trapdoor along the line of action of *W*. Hence option C and D are wrong as direction of *H* is wrong. Tension must act away from the door, hence direction of *T* is wrong. So option A is also wrong.
8	**Ans: D** The vertical component of the acceleration is the centripetal acceleration which is present since the particle is performing circular motion. The horizontal component of the acceleration causes the speed of the object to increase.
9	**Ans: C** $a = v^2/r$, So $v = \sqrt{ar} = \sqrt{120 \times 0.030} = 1.897$ Since ω is constant and $\omega = v/r$ Hence $\omega = \frac{v_1}{r_1} = \frac{v_2}{r_2}$ $v_2 = \frac{v_1}{r_1} \times r_2 = \frac{1.897}{0.030} \times 0.050 = 3.16 \text{ m s}^{-1}$ OR $a = \omega^2 r$ $\omega = \sqrt{(120/0.030)}$ $= 63.25 \text{ rads}^{-1}$ $v = r\omega$ $= 0.050 (63.25)$ $= 3.16 \text{ ms}^{-1}$

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10 Ans: D
The antenna will have the same speed as the space-craft and is still bound in orbit. There is still gravitational force acting on it which causes it to move in circular motion.

11 Ans: A
Let the amount of added heat be Q.
So,
$Q = mc_w\Delta T_w$ …… (1) {heat added to water}
$Q = mc_i\Delta T_i$ …… (2) {heat added to iron}
Eqn. (1) = (2), $\frac{c_w}{c_i} = \frac{\Delta T_i}{\Delta T_w}$
Since cw > ci, ΔTi > ΔTw → the final temperature of iron is going to be higher than the water's final temperature.

12 **Ans: C**
The total volume of the cylinder is not changed. Neither is the total number of molecules. Hence, the average space given to each molecule remains constant. This implies that the average distance between molecules is unchanged.

13 **Ans: B**

$\Delta U = Q + W$

in case (i), W –ve, ΔU +ve (PV ↑ ⇒ T↑), ∴Q +ve

in case (ii), ΔU = 0 since T is constant. W is -ve, thus Q is positive and heat is gained.

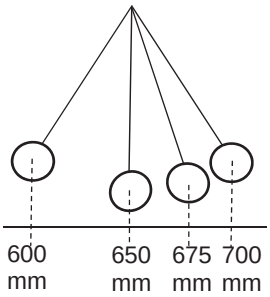
14 **Ans : D**

Taking the initial position at 650 mm mark,

$x = x_0 \sin\omega t = x_0 \sin\left[\left(\frac{2\pi}{T}\right)t\right]$

$25 = 50\sin\left[\left(\frac{2\pi}{2}\right)t\right]$

$t = 0.167$ s



15 **Ans : A**

At x = 0.2 m,
$a = -\omega^2 x$
$20 = -\omega^2(-0.2)$
$\omega = 10$ rad s^{-1}

$v_{max} = \omega x_o = 10 \times 0.2 = 2.0$ m s^{-1}

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16 **Ans: C**

3 x (Period of S) = 30. Hence Period of S= 10 ms

At t = $\frac{1}{4}$ x period of S = 2.5 ms, amplitude of S = displacement of R.

$y = y_o \sin \omega t = y_o \sin [(2\pi/T)t]$

$= 8 \sin [(2\pi/30)x2.5] = 4$ cm

17 **Ans: C**

Since particles A and B are at two sides of a node of a stationary wave, they are anti-phase. Hence phase difference is 180°

Maximum KE is proportional to amplitude. Since amplitude of A < amplitude of B,
$K_A < K_B$

18 **Ans: C**

For diffraction grating: $n\lambda = d \sin\theta$ or $\sin\theta = n\lambda / d$

for n=1, $\sin(15.4) = \lambda / d$ …….(1)
for n=2, $\sin\theta_2 = 2\lambda / d$ ……..(2)
(2)/(1): $\sin\theta_2 = 2 \sin(15.4)$
$\theta_2 = 32.8°$
Angle between first and second maxima = 32.8 – 15.4 = 16.7°

19 **Ans : A**
Terminal p.d. = 1.2 x 80 = 96 V ---(1)
Terminal p.d. = 120 – (1.2+0.40) r ---(2)
Equating (1) and (2), r = 15 Ω

Alternative method:

Let r be the internal resistance of supply and X the resistance of the lower resistor.

p.d. across 80 Ω resistor = p.d. across the lower resistor,

$$X = \frac{1.2 \times 80}{0.40} = 240\ \Omega$$

total current = 1.2 + 0.40 = 1.6 A = supply voltage/total resistance

$$1.6 = \frac{120}{r + \left(\frac{80 \times 240}{80 + 240}\right)}$$

$$r = 15\ \Omega$$

20 **Ans : C**
Energy = QV

21 **Ans : A**
Let $V_R = 0$ V.
$V_Q = 6$ V
$V_P - V_Q = 3$ V $\Rightarrow V_P = 9$ V
$V_P - V_S = 5$ V $\Rightarrow V_S = 4$ V
Hence, $V_{QS} = 6 - 4 = 2$ V and $V_{SR} = 4 - 0 = 4$ V

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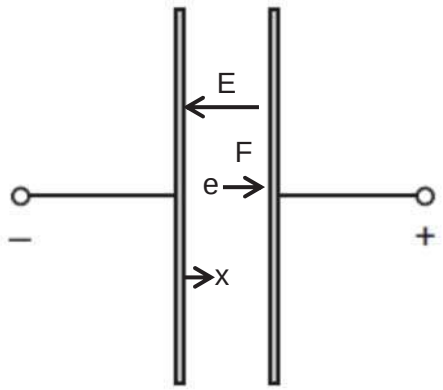
22	**Ans: D**  2 parallel plates, so E is constant → F is constant and in the same direction as x, as shown in the diagram. Potential V increases linearly with x. Since electron is negatively charged, from U = qV, U of electron decreases linearly with x.
23	**Ans: A** Efield lines radiates out of positive charges and enters the negative charge. Efield lines of like charges should repel each other.
24	**Ans: C** As the number of coils is halved, solenoid length is also halved, hence *n* does not change. As $I = V/R$ where $R = \rho L/A$, since *L* is halved, *R* will be halved and *I* will be twice as before. Hence *T* will be twice.
25	**Ans : A** The peak value of the induced e.m.f. , $E_0 = (2\pi f)BAN$ and $T=1/f$ When f is halved, E_0 will halve but T will double.
26	**Ans : D** Power dissipated across a resistor, $P = V_{rms}^2/R$ When V_{rms} is doubled with R unchanged, P will increase 4 times
27	**Ans : B** The number of photoelectrons emitted per second ($\frac{N}{t}$) is directly proportional to the intensity of incident radiation. Since the intensity of radiation is constant, the number of photoelectrons varies proportional with time.
28	**Ans : B** $eV = hc/\lambda_{min}$ higher V means smaller λ_{min} so Q has the higher voltage applied same characteristic X-ray indicates same target material
29	**Ans : B** Based on COE and COM, the kinetic energy of the daughter nuclei is negligible hence the total energy released is shared between β particle and neutrino. Since the highest possible KE of β particle is 13.4 MeV, i.e. when neutrino has zero KE, hence the total energy released by the reaction is also 13.4 MeV, and this value is fixed for this particular reaction. Thus, when an emitted β particle has KE of 6.0 MeV, the associated neutrino must have 13.4 – 6.0 = 7.4 MeV of energy.

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30 **Ans : A**

	X : Y	
Initial	1 : 0	X
After 1 $t_{1/2}$	1 : 1	X | Y
After 2 $t_{1/2}$	1 : 3	X | Y

1 half-life after time t, the number of nuclides of X will reduced by ½ and the number of nuclides of Y will increase by ½. The ratio will then become 1:3.

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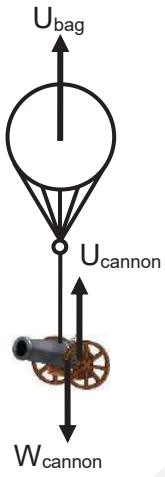
2017 AJC H2 Phy Prelim Solutions
Paper 2 (80 marks)

1ai	Density $\rho = \frac{\text{mass}}{\text{volume}} = \frac{79.72}{\frac{4}{3}\times\pi\times\left(\frac{26.7\times10^{-2}}{2}\right)^3}$ $= 7998.9 \approx 7999$ kg m^{-3}
1aii	$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3\left(\frac{\Delta d}{d}\right) = \frac{0.01}{79.72} + 3\left(\frac{0.1}{26.7}\right)$ $\Delta\rho = 90.87 \approx 90$ kg m^{-3} (to 1 s.f.)
1aiii	$\rho = (8000 \pm 90)$ kg m^{-3}
1bi	 From Newton's 2nd Law Ubag + Ucannon – Wcannon = ma ρ seaVairg + ρ seaVcannong – mg = ma (1050 x 0.70 x 9.81) + (1050 x $\frac{800}{7999}$ x 9.81) – 800 x 9.81 = 800 x a a = 0.49 m s-2
1biv	As the bag and cannon rises, pressure drops due to smaller depth of water, so volume of the lifting bag will increase. (Since temperature is relatively constant), upthrust due to lifting bag increases. For a constant speed of ascent, net force acting on the cannon must be zero. Hence air has to be released to keep the volume of the lifting bag and thus upthrust constant.
2ai	Increasing temperature causes the KE and hence speed of the gas molecules to increase. Constant gas volume and higher speed of the molecules will result in greater frequency of collision and greater change in momentum per collision. These will result in greater average force on the container

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2017 AJC H2 Phy Prelim Solutions
Paper 2 (80 marks)

	and hence increased pressure.
2aii	When the temperature is kept constant, the speed at which the molecules move remain unchanged. But reducing the volume, causes the frequency of collision to increase due to the lesser space for the gas molecules to move in. Pressure increases due to the increased frequency of collision by the gas molecules.
2bi	Assuming internal PE is zero (or gas is ideal), $\frac{1}{2}mv^2 = \frac{3}{2}kT$ $v_{rms} = \sqrt{\frac{3kT}{m}}$ Given m is 1u = 1.66 x 10^{-27} kg, $v_{rms} = \sqrt{\frac{3(1.38 \times 10^{-23})(3.5)}{1.66 \times 10^{-27}}}$ V_{rms} = 295 m s^{-1}
2bii	Since there is 1 H atom per cm^3, density ρ = 1.66x 10^{-27} kg cm^{-3} = 1.66 x 10^{-21} kg m^{-3} $P = \frac{1}{3}\rho v_{rms}^2 = \frac{1}{3}(1.66 \times 10^{-21})(295)^2$ P = 4.8 x 10^{-17} Pa OR $PV = NkT$ P(1 x 10^{-6}) = (1)(1.38 x 10^{-23})(3.5) P = 4.8 x 10^{-17} Pa

3ai	Simple harmonic motion is the motion of a body such that its acceleration is proportional to its displacement from a fixed point and is always directed towards that point.
3aii	Correct shape – smooth curve ($E_p \propto x^2$), symmetrical about EPE axis， max EPE at max displacement (± 2.0 cm), zero E_p at zero displacement Correct value of max EPE = 2.4 ± (0.1) mJ Scale marked, appropriate choice of scale Note: Max EPE = Max KE= $\frac{1}{2}m(\omega x_0)^2 = \frac{1}{2}m\left(\frac{2\pi}{T}\right)^2 {x_0}^2 = 0.5(0.170)\left(\frac{2\pi}{2.25/3}\right)^2 (0.020)^2 = 2.4\,\text{mJ}$

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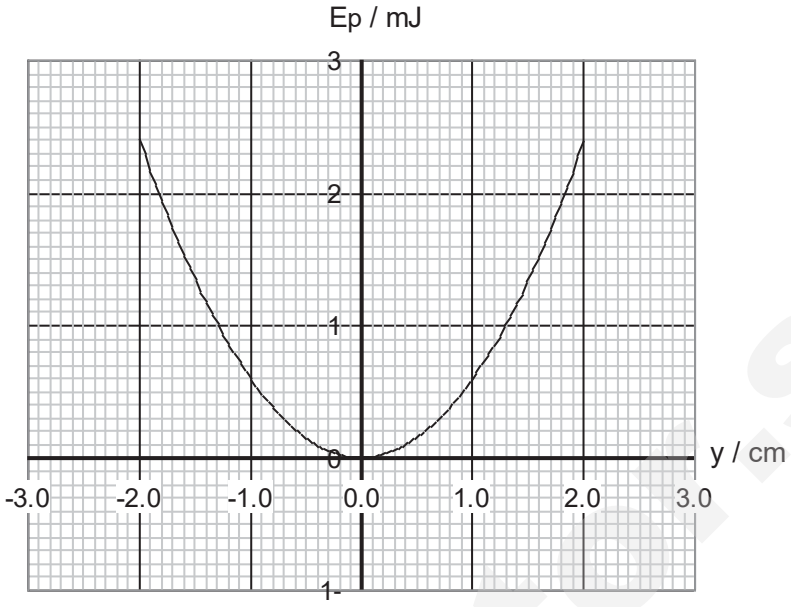
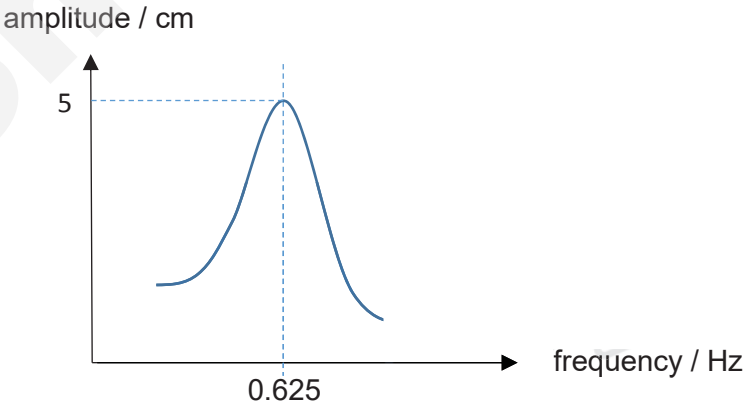
Paper 2 (80 marks)

	
3bi	$\frac{1}{1.6} = 0.625$
3bii1	The rotating drum exerts a periodic force on the system. As a result, the system undergoes forced oscillation.
3bii2	The amplitude reaches a maximum value when the period of the force exerted by the inner drum is 1.6 s, which is the natural period of the system
3biii	 Correct label of resonant frequency 0.625 Hz and max amplitude of 5 cm. Correct shape
3biv	Without the concrete, the machine's centre of mass is higher This will result in less stability of the washing machine when the machine is

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Paper 2 (80 marks)

	spinning at high speeds. OR Without the concrete, the mass of the system is smaller, hence period of oscillation is shorter. This will lead to excessive large amplitude of vibration in spin mode as machine spins at high speed.

4ai	$R_{eff} = \left(\frac{1}{4.0} + \frac{1}{2.0}\right)^{-1} + 2.0$ $= 3.33\ \Omega$
4aii	X, Z, Y. The brightness of the bulbs depends on the power dissipated in them. Comparing bulbs X and Z, since they are in parallel, the voltage drop across them is the same, and using $P = V^2/R$, we conclude that bulb Z is brighter than bulb X. Next, use $P = I^2R$ to compare between bulbs Y and Z, and bulb Y is brighter as the current through Y is larger.
4bi	Using the potential divider principle on the upper circuit, $V_{AB} = 6.0\left(\frac{2.0}{1.0 + 2.0}\right)$ $= 4.0$ V
4bii	At null deflection, terminal p.d. of the lower circuit = $3.0\left(\frac{3.33}{3.33 + 0.50}\right) = 2.608$ V $\frac{L_{AC}}{L_{AB}} = \frac{V_{AC}}{V_{AB}}$ $\frac{L_{AC}}{100.0} = \frac{2.608}{4.0} \Rightarrow L_{AC} = 65.2$ cm
4biii	With a lower resistance bulb used for X, the effective resistance of the three bulbs (in a(i)) will decrease. Hence, the terminal potential difference across the cell in the lower circuit decreases. The balance length AC must be **shorter** for null deflection to occur.

5ai	Direction is X → Y

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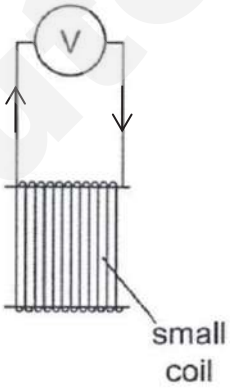
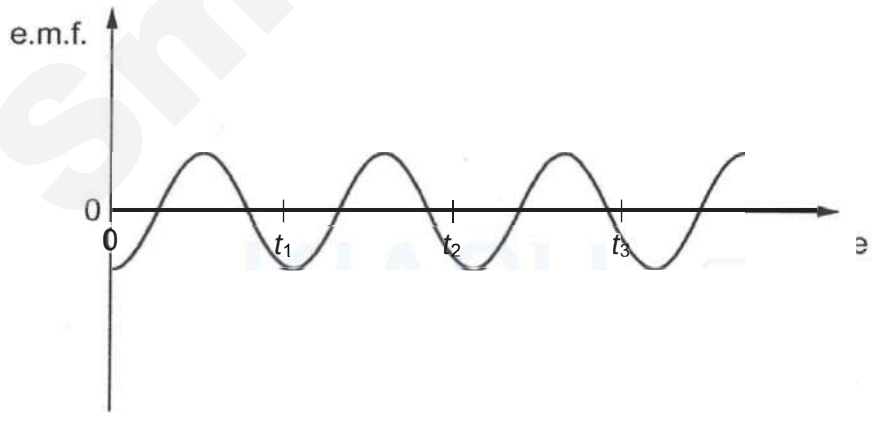
Paper 2 (80 marks)

5aii1.	The e.m.f. induced in a conductor is proportional to the rate of change of magnetic flux linkage. Flux in solenoid is increasing. Hence, flux in small coil is also increasing, so e.m.f. induced.
5aii2.	The direction of the induced e.m.f. is such that it tends to produce effects to oppose the change causing it. The magnetic field set up in the small coil will oppose/be in opposite direction to the increasing field in solenoid. Direction of induced current marked correctly on diagram (Induced current is in the clockwise direction through the voltmeter.) 
5aiii	 cosine curve about time axis correct frequency (ignore phase) $I = I_0 \sin\omega t + A$ where $A > 0$ Since $B \propto I$, $\varepsilon = -\frac{d(NBA)}{dt} = -NA\frac{dB}{dt}$ Hence, $\varepsilon \propto -\cos\omega t$

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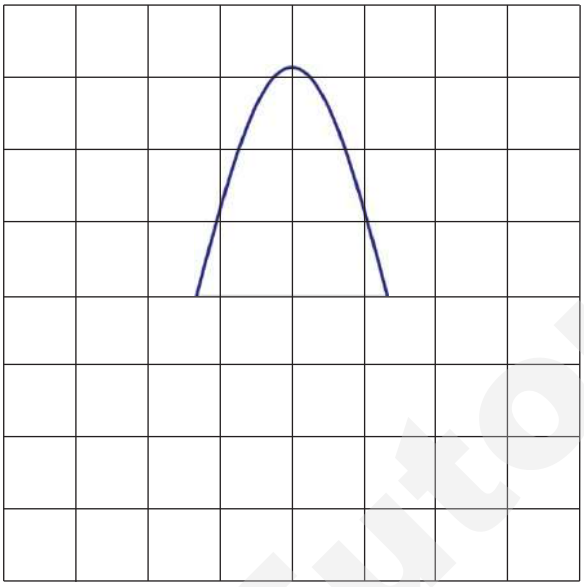
Paper 2 (80 marks)

5bi	$I = \frac{P}{V} = \frac{1.5}{6.0} = 0.25$ A
5bii	

6a i	screen will be <u>uniformly</u> bright
6a ii	Concentric bright rings spacing between rings increases and intensity of rings decreases radially outwards
6b i	$\Delta p_x = \frac{h}{\Delta x}$ $= \frac{6.63 \times 10^{-34}}{1.00 \times 10^{-10}}$ $= 6.63 \times 10^{-24}$ *kgms*$^{-1}$
6b ii	p = mv = $(9.11 \times 10^{-31})(3.00 \times 10^{7}) = 2.73 \times 10^{-23}$ kg m s^{-1} comparison of Δp_x with value of p to show significance: e.g.

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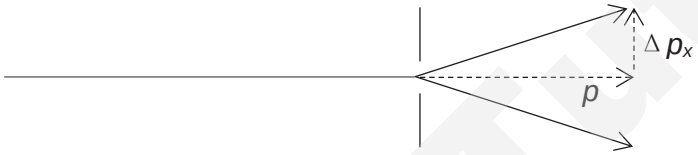
	$\frac{6.63x10^{-24}}{2.73x10^{-23}} x100\% = 24\%$ Δp_x *is 24% of* p **or** $\Delta p_x \approx 0.24\, p$ This means there is a high uncertainty in the angle which the electron can be scattered (or the angle which the electron can be scattered is significant) **or** there is high uncertainty in the direction that the electron will emerge (or the emerging electron can be travelling in a significant range of directions) *Note for understanding:*  Before the slit, uncertain about the electron position hence more certain about its momentum, ie. direction travelling towards slit. At the slit, greater certainty of the electron vertical position (ie. Δ x small), then there will be greater uncertainty in momentum vertically (Δp_x *high), ie. not so sure about its direction after passing through the slit.*

7ai	Electrical energy to (mechanical energy) to sound energy OR Sound energy to (mechanical energy) to electrical energy
7aii	Ultrasound is a wave in which the displacements of the particles in the wave are along the direction of transfer of energy of the wave and Light is a wave in which the directions of the oscillations of electric field and magnetic field are perpendicular to each other and at right angles to the direction of transfer of energy of the wave. Or ultrasound is longitudinal and light is transverse Or ultrasound needs medium for propagation but light can propagation in vacuum Or ultrasound cannot be polarised and light can be polarised.

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Paper 2 (80 marks)

<table>
<tr><td></td><td></td></tr>
<tr><td>7bi</td><td>0.027</td></tr>
<tr><td>7bii</td><td>Exposure time = $\frac{\text{absorbed dose}}{\text{dose - rate}} = \frac{240 \times 10^3}{200}$
= 1200 s</td></tr>
<tr><td>7ci</td><td>Plotting SF on a logarithmic scale allows separation of the curves at small values of SF to be increased.</td></tr>
<tr><td>7cii</td><td>
<table>
<tr><th>absorbed dose / kJ kg^{-1}</th><th>$\log_{10}(SF)$</th></tr>
<tr><td>50</td><td>– 0.65</td></tr>
<tr><td>100</td><td>–0.90</td></tr>
<tr><td>160</td><td>–1.18 OR –1.20</td></tr>
<tr><td>240</td><td>–1.55 OR –1.58</td></tr>
<tr><td>340</td><td>–2.13 OR –2.15</td></tr>
<tr><td>450</td><td>–2.85</td></tr>
<tr><td>560</td><td>–3.75 OR –3.78</td></tr>
</table>
3 marks for all (7) answers recorded correctly
2 mark for at least 4 answers recorded correctly
1 mark for at least 2 answers recorded correctly
.
</td></tr>
<tr><td>7ciii</td><td>$\log_{10}(SF)$ = –1.18 OR –1.20
SF = 0.0661 or 0.0631</td></tr>
</table>

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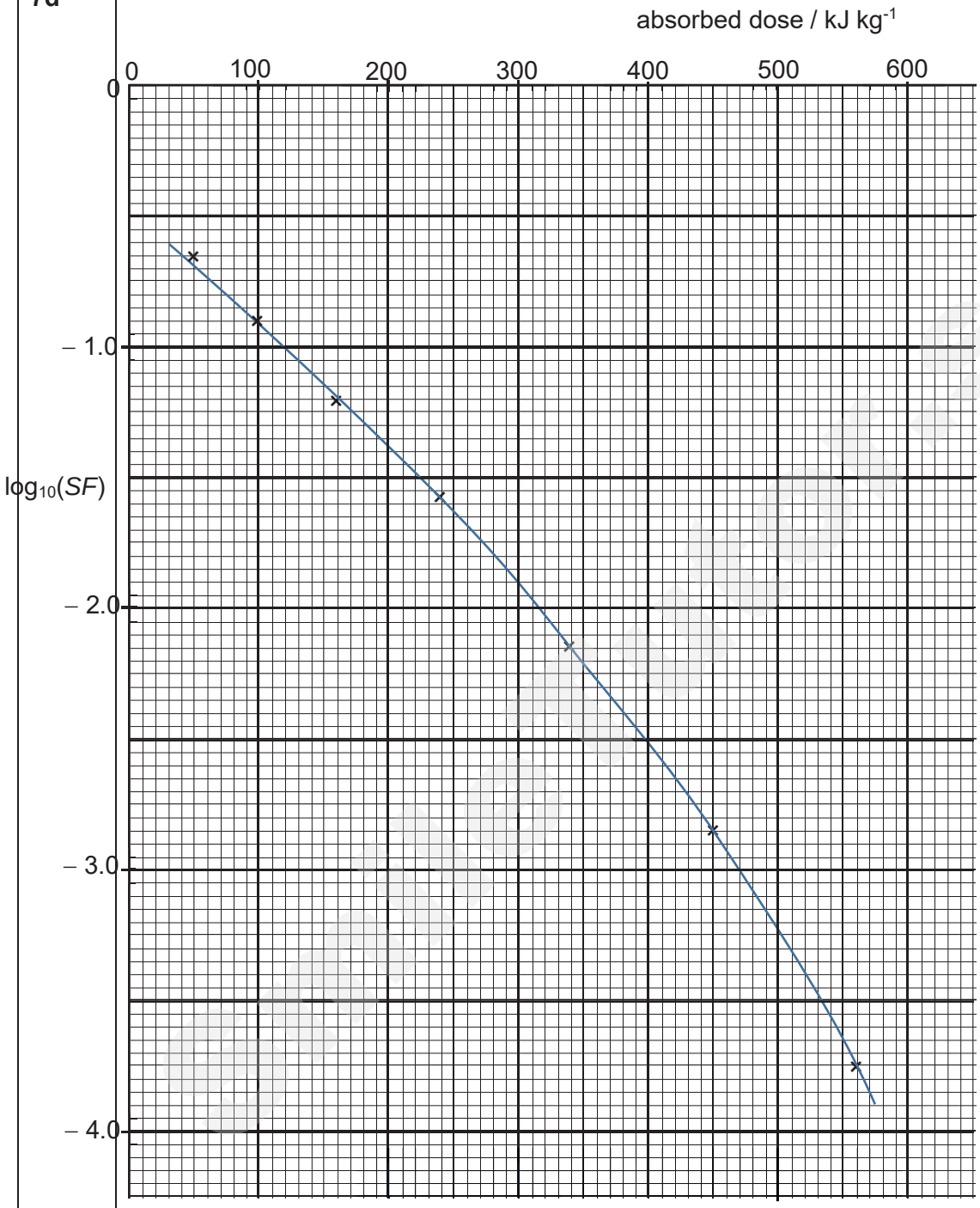
Paper 2 (80 marks)

7d



2 marks for all points plotted correctly (accuracy up to half of a small square)

1 mark for at least 4 points plotted correctly (accuracy up to half of a small square)

1 mark for best fit curve (number of points on either side of curve differ by 1)

7ei	There are dips in the curves at (about) 200 W kg^{-1} for the higher absorbed doses.
7eii	The curve is almost linear at low doses,

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Paper 2 (80 marks)

	and the curve becomes steeper at higher doses
7fi	The value of $\log_{10} (SF)_R$ for the absorbed dose of 560 kJ kg^{-1}can be determined from Fig. 7.4 as the graph is $\log_{10}(SF)_R$ vs absorbed dose. $(SF)_R$ is then calculated from it.
7fii	$\log_{10} (SF)_R = \log_{10} [(SF)_1 \times (SF)_2] = \log_{10} (SF)_1 + \log_{10} (SF)_2$ The linear part of Fig. 7.4 could represent the effects due to $(SF)_1$. The linear part is extrapolated to determine the value of $\log_{10} (SF)_1$ at 560 kJ kg^{-1} and hence $(SF)_1$ The value of $\log_{10} (SF)_2$ is determined by subtracting the value of $\log_{10} (SF)_1$ from the value of $\log_{10} (SF)_R$ at 560 kJ kg^{-1}. Hence, $(SF)_2$ can be determined.

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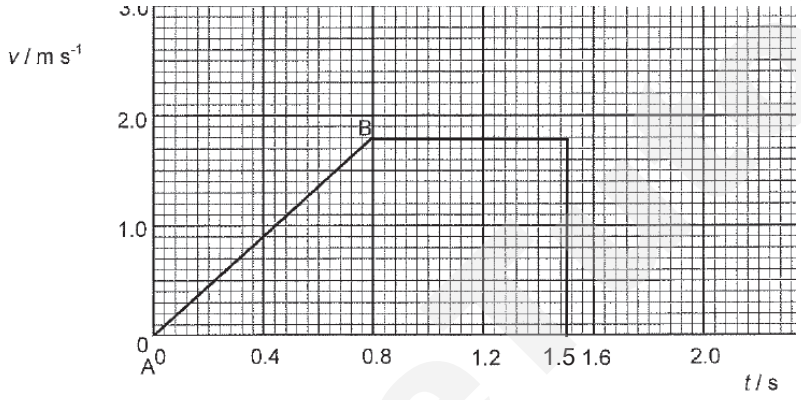
2017 AJC prelim Physics H2P3 Solutions
Paper 3 (80 marks)

1a	Acceleration = gradient of graph = 1.80 / 0.80 = 2.25 ≈ 2.3 m s^{-2}
1b	Distance = area under the graph = (1.80 x 0.80) / 2 = 0.72 m
1ci	Time = distance BC / speed = (2.0 – 0.72) / 1.8 = 0.71 s
1cii	Straight horizontal line until 1.5 s Steep line to zero speed (ignore gradient) 
1ciii	KE gain by trolley and M = GPE loss by M ½ x (0.80 + M) x 1.8^2 = M x 9.81 x 0.72 M = 0.24 kg

2ai	At P, $\phi_p = -\frac{2GM}{D} - \frac{2GM}{D}$ $\phi_p = -\frac{4GM}{D}$
2aii	From P to X, Gain in KE = Lost in GPE $\frac{1}{2}mv_x^2 = [-\frac{4GM}{D} - (-\frac{2GM}{D/2} - \frac{2GM}{D/2})]m$ $\frac{1}{2}v_x^2 = \frac{4GM}{D}$ $v_x = \sqrt{\frac{8GM}{D}}$

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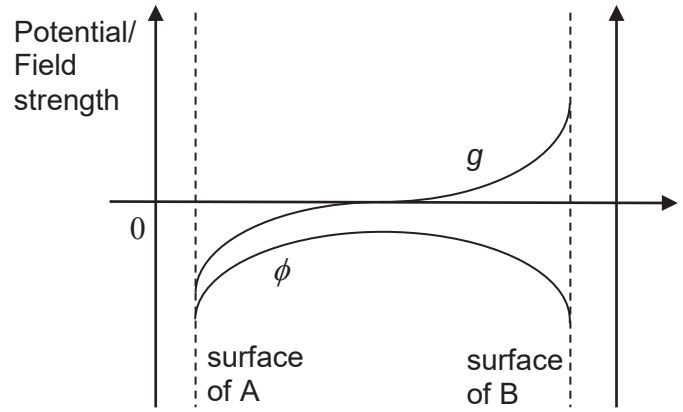
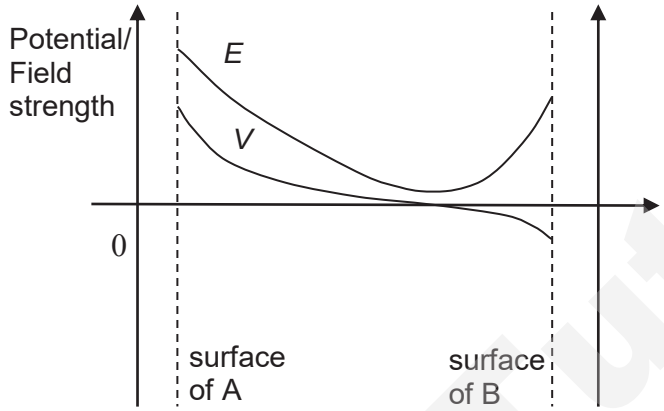
2bi	 *g* – cuts horz axis at centre, positive and negative values. ϕ - symmetrical about centre and all values are negative.
2bii	 E – All values positive, turning point to the right hand side of centre. V – cuts horz axis to the right of the centre pt. Positive and –ve value. Gradient is non-zero at horz intercept.
2biii	Body will move towards the left (away from A) as resultant g-field is much weaker than resultant E-field, direction of motion will be influenced by E-field. Or as repulsive electric force by A on mass at R is larger than attractive force by B on mass at R; and the attractive gravitational force by both A and B on mass at R is negligible as compared to net replusive electric force.

3a	At B, pV = nRT $(4.3 \times 10^{6})(1.2 \times 10^{-3}) = 3.0 \times 8.31 \times T$ T = 207 K = 210 K
3b	At C, pV = nRT $(2.2 \times 10^{6})(3.8 \times 10^{-3}) = 3.0 \times 8.31 \times T$ $\therefore T = 335$ K For monatomic ideal gas, Internal energy, *U* = total KE of all molecules, since PE = 0 $\therefore U = 3/2\ nRT$ $\therefore$ change in internal energy, $\Delta U = 3/2\ nR\Delta T$ or $3/2\ Nk\Delta T$ From B to C, $\Delta U = 3/2\ nR\Delta T$ $= 3/2 \times 3.0 \times 8.31 \times (335 - 207)$ OR $\Delta U = 3/2\ NK\Delta T$ $= 3/2 \times 3.0 \times (6.02 \times 10^{23}) \times (1.38 \times 10^{-23}) \times (335 - 207)$

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	ΔU = 4790 J = 4800 J
3c	Work done from B to C = area under graph from B to C WD by gas = ½ (4.3 +2.2) x 10^6 x (3.8 – 1.2) x 10^{-3} = + 8450 J (gas expansion) = +8500 J
3d	By 1st Law of Thermodynamics, for process BC, $\Delta U = Q + WD$ $\therefore$ 4790 = Q + (−8450) $\therefore$ heat absorbed by gas in process BC, Q = 13240 J = + 1.32 x 10^4 J

4a	Only transverse wave can be polarized.
4bi	Use Malus' law, Intensity $I = I_o \cos^2 \theta$ Intensity $I = I_o \cos^2 \theta = I_o \cos^2 45° = I_o/2$ Emergent beam is polarised at 45° clockwise from vertical
4bii	Intensity $I = (I_o \cos^2 45°) \cos^2 45° = I_o/4$ Emergent beam is polarised vertically

5a	**Diffraction** is the spreading of waves when they pass through an opening or round an obstacle. (Diffraction effects are the greatest when the width of the opening is comparable with the wavelength of the waves.)
5bi	Angle subtended θ = (10 x 10^{-3})/40 = 2.5 x 10^{-4} rad
5bii	Rayleigh's criterion for two images to be just resolved is when one central peak (central maximum) falls at the first dark fringe (first minimum) for the second diffraction pattern, i.e the minimum angular separation of the 2 images is $\theta_{min} \approx \lambda/b$. $\theta_{min} \approx \lambda/b$ = (600 x 10^{-9}) / (1.5 x 10^{-3}) = 4.0 x 10^{-4} rad. Since angle subtended θ is smaller than the θ_{min}, therefore the images observed cannot be resolved
5ci	waves (from slits) overlap (at point X) path difference (from slits to X) is zero or phase difference (between the two waves) is zero so constructive interference gives bright fringe
5cii	difference in distances = λ / 2 = 580 / 2 = 290 nm
5ciii	$\lambda = ax / D$ D = [0.41 × 10^{-3} × (**2 × 2.0 × 10^{-3}**)] / 580 × 10^{-9} = 2.8 m

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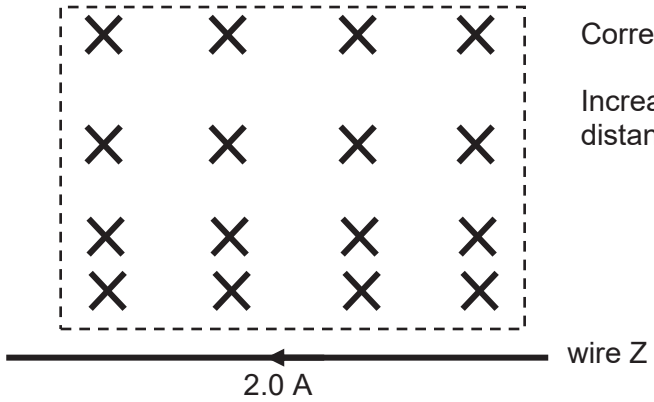
6a



Correct direction of B

Increasing spacing with increasing distance from wire Z (at least 3 rows)

b

Ion moves (or spirals /curves) anticlockwise (or towards the right) with decreasing radius.

By FLHR, magnetic force is directed to the right perpendicular to v at point P. Hence ion is deflected to the right.

As radius of curvature is inversely proportional to magnetic flux density, radius decreases as magnetic flux density increases as ion approaches wire Z.

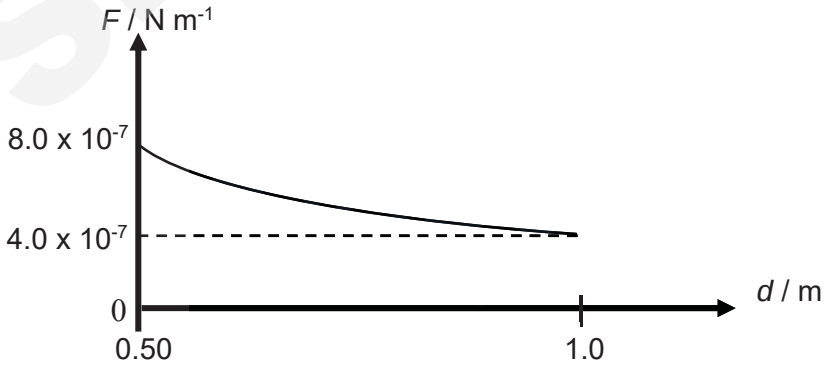
NOTE:
(Student only needs to describe the path for particle approaching wire. If students discussed beyond that, marks can only be awarded if there is sound physics.

If student extends to discuss particle reaches a closest approach from wire and moves away from wire, the radius of curvature should increase as magnetic flux density decreases.)

ci

$$B = B_Z - B_Y$$
$$= \frac{\mu_0 I_Z}{2\pi r} - \frac{\mu_0 I_Y}{2\pi r}$$
$$= \frac{(4\pi x\ 10^{-7})}{2\pi(0.5)}(2.0 - 1.0)$$
$$= 4.0 \times 10^{-7}\ \text{T}$$

cii



Correct trend as $F \propto \frac{1}{d}$

F at 0.50 m is twice the amount at 1.0 m. (values not required)

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7 a	By conservation of momentum, since initial momentum of meson is zero as it is stationary, total final momentum of the photons is zero, hence the photons must be equal in magnitude and opposite in direction. Since photons have equal momentum, ρ , they have same wavelength (ie. same frequency) and hence equal energy, E.
7b i	2 (Energy of photon) = Energy released $= m c^2$ Energy of photon = $(\frac{2.4 \times 10^{-28}}{2})(3.00 \times 10^8)^2$ $= 1.08 \times 10^{-11}$ J
7b ii	$E = hc / \lambda$ $\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (1.08 \times 10^{-11})$ $= 1.84 \times 10^{-14}$ m
7b iii	$\lambda = h / p$ $p = (6.63 \times 10^{-34}) / (1.84 \times 10^{-14})$ $= 3.6 \times 10^{-20}$ N s **OR** $E = pc$ $1.08 \times 10^{-11} = p (3.00 \times 10^8)$ $p = 3.6 \times 10^{-20}$ N s

8ai	The **resistance** of a conductor is the ratio of the potential difference across it to the current flowing through it.
8aii	The **ohm** is the resistance of a conductor in which the current is 1 ampere when a potential difference of 1 volt is applied across it.
8b	
8c	When the temperature increases, the resistance of a filament lamp increases while the resistance of a semiconductor decreases. For a filament lamp, there is little increase in the number of charge carriers/electrons. The increase in amplitude of vibration of the atoms causes the resistance to increase with temperature. For a semiconductor, the increase in the number of charge carriers/electrons is more significant than the increase in amplitude of vibration of the atoms. This causes the resistance to decrease with temperature.

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8di

Use $R = \frac{\rho l}{A}$

$$= \frac{(5.5 \times 10^{-8})(2.0)}{\left(\frac{\pi(0.020 \times 10^{-3})^2}{4}\right)}$$

$$= 350\ \Omega$$

power dissipated = $I^2R = (0.42)^2(350) = 62$ W

8dii1

Mthd 1

Common current in both wires,
so *nAv* for tungsten= *nAv* for copper.

$$v_{tungsten} = \frac{n_{copper}A_{copper}v_{copper}}{n_{tungsten}A_{tungsten}}$$

$$= \frac{(8.0)(1.4^2)(0.021 \times 10^{-3})}{(3.4)(0.02^2)}$$

$$= 0.24\ \text{m s}^{-1}$$

Mthd 2

Use $I = nAve$

$$v_{tungsten} = \frac{I}{n_{tungsten}A_{tungsten}e}$$

$$= \frac{0.42}{(3.4 \times 10^{28})(\pi\frac{(0.02 \times 10^{-3})^2}{4})(1.60 \times 10^{-19})}$$

$$= 0.25\ \text{m s}^{-1}$$

Note that v is the drift speed and not the actual speed of the electrons.

8dii2

The higher speed of the electrons in tungsten means that they have a much greater kinetic energy than those in copper.
As the electrons collide with the fixed atoms,
energy is lost to these atoms, resulting in a rise in temperature.

8diii

Any one – high resistivity, high melting point, should not oxidise at high temperature (to ensure long life), non-corrosive

8ei

Mthd 1

resistance of thermistor at 0 °C = 3900 Ω
using potential divider principle,

$$\left(\frac{R}{R + 3900}\right) \text{x} 1.50 = 1.00$$

R = 7800 Ω

Mthd 2

p.d. across thermistor = 1.50 – 1.00 = 0.50 V
resistance of thermistor at 0 °C = 3900 Ω
common current in circuit = $\frac{1.00}{R} = \frac{0.50}{3900}$

R = 7800 Ω

8eii

Mthd 1

resistance of thermistor at 30 °C = 1250 Ω
using potential divider principle,

$$\text{voltmeter reading} = \left(\frac{7800}{7800 + 1250}\right) \text{x} 1.50$$

$$= 1.29\ \text{V}$$

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	Mthd 2 resistance of thermistor at 30 °C = 1250 Ω common current, I in circuit = $\frac{1.50}{R+1250} = \frac{1.50}{7800+1250} = \frac{1.50}{9050}$ voltmeter reading = IR = 1.29 V
8eiii	resistance of thermistor at 0 °C = 3900 Ω effective resistance of R and voltmeter = 7800/2 = 3900 Ω (same as thermistor's) voltmeter reading = p.d. across X = 1.50/2 = 0.750 V

9 a 1.	photon is a packet/quantum of energy of electromagnetic radiation (photon) energy = h × frequency
2.	every particle has an (associated) wavelength wavelength = h / p , where p is the momentum (of the particle)
9bi	for a wave, electron can 'collect' energy continuously for a wave, electron will always be emitted / electron will be emitted at all frequencies after a sufficiently long delay
9bii 1.	either wavelength is longer than threshold wavelength or frequency is below the threshold frequency or photon energy is less than work function
9bii 2.	$hc / \lambda = \phi + E_k$ $(6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (240 \times 10^{-9}) = \phi + 4.44 \times 10^{-19}$ $\phi = 3.8 \times 10^{-19}$ J (allow 3.9×10^{-19} J)
9biii1.	photon energy larger so (maximum) kinetic energy is larger
9biii2.	fewer photons (per unit time) so (maximum) current is smaller
9ci1.	arrow from –0.54 eV to –0.85 eV, labelled L
2.	arrow from –0.54 eV to –3.4 eV , labelled S (two correct arrows, **but only one label** – allow 2 marks) (two correct arrows, **but no labels** – allow 1 mark)
9cii	$E = hc / \lambda$ $(3.4 – 0.54) \times 1.6 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda$ $\lambda = 4.35 \times 10^{-7}$ m
9ciii	–1.50 → –3.4 = 1.9 eV –0.85 → –3.4 = 2.55 eV (allow 2.6 eV) –0.54 → –3.4 = 2.86 eV (allow 2.9 eV)

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JC2 Prelim Question 1 MS

Q1	Answer	Mark	Code
(b)(i) MMO	***Measurement of d*** Value of d with unit and to nearest 1 mm.	1	**M1**
(b)(ii) ACE	***Estimating uncertainties*** Percentage uncertainty in d calculated correctly to 2 s.f using sensible value of Δd (e.g. 2 mm ≤ Δd ≤ 4 mm).	1	**A1**
(b)(iii) MMO ACE	***Calculation of T*** Evidence of repeated readings for raw time and NT > 10 s Correct calculation of T to 3 s.f. with unit.	1 1	**M2** **A2**
(c) PDO ACE	3.0 cm ≤ 2nd d ≤ 10.0 cm 2nd T calculated correctly Higher/lower 2nd d , higher/lower 2nd T Two values of k calculated correctly with correct units Valid conclusion relating to the calculated values of k, testing against a stated criterion.	1 1 1 1 1	**M3** **A3** **A4** **A5** **A6**
(d) ACE	Oscillations are too quick to timed accurately. OR Magnets may stick together in this small separation.	1	**A7**
(e) APLE	Placed each lump at equal distance from the axis of rotation of (top) bar magnet and measure the period Vary the distance between the 2 masses d between the magnets kept the same	1 1 1	**PL1** **PL2** **PL3**

JC2 Prelim Question 2 MS

Q2	Answer	Mark	Code
(b)(i) MMO	***Measurement of F*** Values of F to 0.01 N and d to 0.1 cm.	1	**M1**
(b)(ii) MMO	***Set up apparatus from a diagram and follow of written instructions*** 6 sets of readings with correct trend. Reasonable intervals between values of d (> 5cm) and range of $d \geq 80$ cm. All values of F to 0.01 N and d to 0.1 cm.	1 1 1	**M2** **M3** **M4**
(b)(iii) ACE	***Evaluation on keeping rule horizontal*** Use metre rule to measure distance from the bench at two different points on the rule to ensure the rule is horizontal.	1	**A1**
(c) PDO	***Graph*** Points correctly plotted. Line of best fit	1 1	**P1** **P2**
(d) ACE	***Value of m calculated correctly from y-intercept*** Y-intercept must read off to the nearest half small square or determine from y = mx + c using a point on the line. Correct calculation and unit of m. Values of m between 80 to 120 g.	1 1 1	**A2** **A3** **A4**

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JC2 Prelim Question 3 MS

Q3	Answer	Mark	Code
(a)(i) MMO	***Measurement of d*** Record zero error and take repeated readings for d. Value of d in the range 0.15 mm ≤ d ≤ 0.25 mm, with unit to nearest 0.01 mm.	1	**M1**
(a)(ii) ACE	***Calculation of A*** Calculation of A in m^2 with same significant figure as d.	1	**A1**
(d) MMO	***Set up apparatus from a circuit diagram and follow of written instructions*** • Award 2 marks if the student has successfully collected 6 or more sets of data (l, V_1, V_2), with $V_1>V_2$, without assistance/intervention. • Award 1 mark if student has successfully collected 5 sets of data (l, V_1, V_2) , with $V_1>V_2$, without assistance/intervention. • Award zero mark if student has successfully collected 4 or fewer sets of data (l, V_1, V_2) without assistance/intervention. • Deduct 1 mark if student requires some assistance/intervention but has been able to do most of the work independently. Indicate the nature of any assistance. • Deduct 2 marks if student has been unable to collect data without substantial assistance/intervention. Minimum mark for **M2** = 0.	2	**M2**
(d) MMO	***Range of l*** Range of $l \geq 30$ cm.	1	**M3**
(d) PDO	***Layout: Column headings (raw data & calculated quantities: l, V_1, V_2, V_1/V_2)*** Each column heading must contain an appropriate quantity and a unit. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit i.e. solidus is expected.	1	**P1**
(d) PDO	***Table of results: raw data (appropriate degree of precision)*** ALL values of l to nearest mm and V_1 & V_2 to nearest 0.001 V.	1	**P2**
(d) PDO	***Table of results: calculated quantities (appropriate no. of significant figures)*** Calculated values of V_1/V_2 should consistently be to the same no. of s.f. as the raw data. ALL values of V_1/V_2 are given to 3 s.f. for this mark to be awarded.	1	**P3**
(d) ACE	***Table of results: calculated quantities*** Correctly calculated values of V_1/V_2. Allow one slip in computation.	1	**A2**
(e) ACE	***Linearising Equation*** Linearising equation and deriving expressions that equate e.g. gradient to P and y-intercept to Q.	1	**A3**
(e) PDO	***Graph: Layout, choice of scale and labeling of axes*** Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Axes must be labelled with the quantity which is being plotted.	1	**P4**

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Q3	Answer	Mark	Code
(e) PDO	**Graph: plotting of points** All observations must be plotted. Check any 3 points and put ticks if correct. Work to an accuracy of half a small square.	1	**P5**
(e) PDO	**Graph: trend line and ability to draw best fit line** Straight line of best fit – judge by scatter of points about the student's line. There must be a fair scatter of points on either side of the line.	1	**P6**
(e) ACE	***Interpretation of graph – gradient*** Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for Δy/Δx (do not allow Δx/Δy). Value of P = candidate's gradient with correct unit m^{-1}.	1	**A4**
(e) ACE	***Interpretation of graph – intercept*** y-intercept – must be read off to nearest half a small square or determined from $y = mx + c$ using a point on the line. Value of Q = candidate's y-intercept and Q has no unit.	1	**A5**
(f) MMO	***Identification of anomaly*** Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment of absence of anomalous data. Possible answer for anomalous point The point (x, y) is an anomalous point because it is far away from the best fit line. This could be due to the difficulty in clipping crocodile clips tightly to the wire attached to metre rule.	1	**M4**
(g)(i) ACE	***Drawing conclusions*** Value of ρ calculated correctly with unit Ω m. Range of ρ in the range of 1.0 – 20.0 x 10^{-7} Ω m.	1	**A6**
(g)(ii) ACE	***Interpretation of graph – underlying principles*** Steeper gradient with the same intercept and line is labelled Z.	1	**A7**
(h)(i) ACE	***Sources of errors*** Relevant point might be: 1. It is difficult to measure l because the crocodile clip has a broad width. This will affect the accuracy of l.	1	**A8**
(h)(ii) ACE	***Improvement*** Relevant point might be (correspond to sources of errors): 1. Replace the crocodile clip with a sliding jockey or a narrower clip to reduce the error in l measured.	1	**A9**

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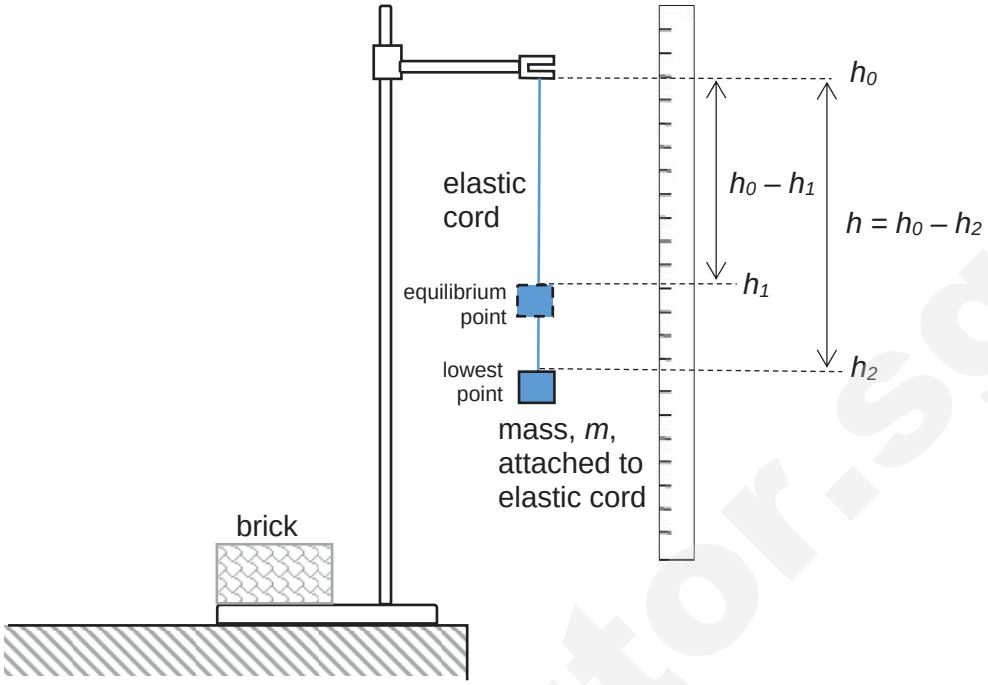
Suggested Solution to Q4

Diagram



Define problem

To test the relationship between h and k, and determine value of g.

Procedure

1. Setup the experiment as shown in the diagram above.
2. Measure and record mass, m, of the given object using an electronic balance.
3. Hang the elastic cord from clamp of the retort stand. Measure and record the initial height h_0 of mass m at its starting position using a metre rule.
4. Lower the attached mass m and allow it to come to rest.
5. Measure record the height h_1 of mass m at its equilibrium position using a meter rule, determine the spring constant k using $\frac{mg}{(h_0 - h_1) - L}$, where L is 50.0 cm.
6. Bring the mass m back to its initial height h_0 and drop it from rest.
7. Measure and record the lowest height reached by the mass, h_2 using a metre rule.
8. Determine the height fallen by the mass m, h using $h = h_2 - h_0$
9. Repeat the experiment using different elastic cords to obtain 6 sets of values for h and k.

Control of variables

1. Mass of object used is kept constant by using the same mass throughout the experiment.

Analysis

$$\frac{(h-L)^2}{h} = \frac{2mg}{k}$$

Plot a graph of $\frac{(h-L)^2}{h}$ against $\frac{1}{k}$ where the gradient is $2mg$ and y-intercept is zero.

Relationship is valid if the graph is a straight line passing through the origin.

Value of g can be determined from $\frac{gradient}{2m}$.

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Safety and Accuracy

1. Take preliminary readings to locate approximate lowest height h_2 / to prevent object hitting surface
2. Ensure that the position of the metre rule is not shifted during the experiment by clamping it to a retort stand.
3. Use set square to ensure that metre rule is vertical
4. Use a set square as a marker, repeat the experiment a few times to better locate the lowest position of the mass h_2 / *OR*
   Use of video camera with slow motion or frame by frame playback to determine lowest position of mass *m* / OR
   Place a motion sensor directly beneath the mass m to record its displacement from the sensor. Lowest position of the mass could be read off from the datalogger.
5. Ensure that cord obeys Hooke's law and has not exceeded proportional limit by checking the *L* remains unchanged after the experiment.
6. Use sand tray to catch falling object to prevent mass / cord from hitting a person.
7. Use goggles / safety screen to prevent mass / cord from hitting a person
8. Use a heavy mass to stabilize the retort stand to prevent setup from toppling.

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Anglo-Chinese Junior College

JC2 Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9749**
Paper 1 Multiple Choice 29 August 2017
1 hours

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your Name and Index number in the answer sheet provided.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this Question Paper.

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DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/^oC + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

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1 Which of the following gives the best estimate of the typical cruising speed of a 300-seater commercial passenger aircraft?

A 1,000 km h^{-1}

B 1,500 km h^{-1}

C 2,000 km h^{-1}

D 2,500 km h^{-1}

2 A student measured the diameter of a coin using a vernier calipers and found it to be
(5.06 ± 0.04) mm.

Which if the following procedures will most significantly reduce the fractional uncertainty when determining the diameter of a coin?

A Use a micrometer screw guage and take one reading

B Account for the zero error of the vernier calipers and take one reading

C Taking six readings using the vernier calipers and take the average of the readings

D Measure the diameter of the three identical coins placed side by side and divide the reading by three

3 A car accelerates uniformly from rest and reaches a speed of 30 m s^{-1} in 50 m.

If the car continues to accelerate at the same rate, what is the time taken for it to travel another 250 m?

A 4.8 s **B** 7.5 s **C** 11.5 s **D** 14.6 s

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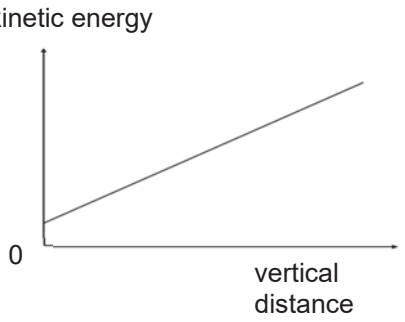
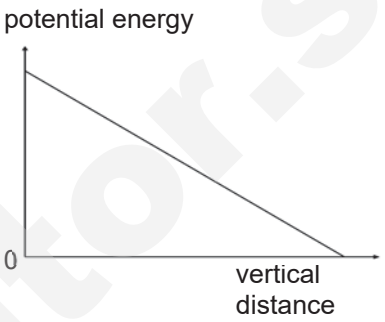
4 A stone was projected horizontally off a cliff as shown.



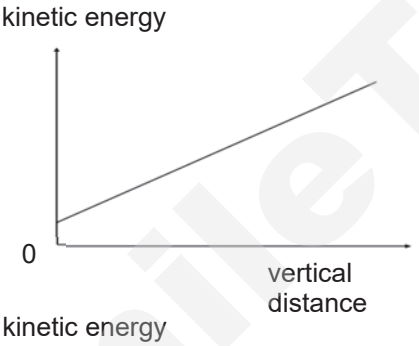
Ignoring air resistance, which graphs show the variation of kinetic energy and gravitational potential energy with the vertical distance?

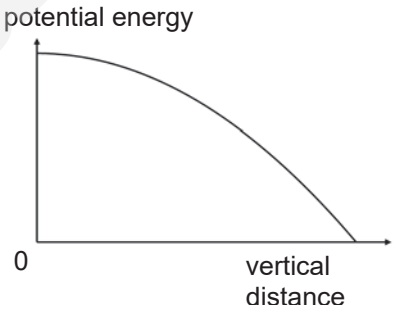
A



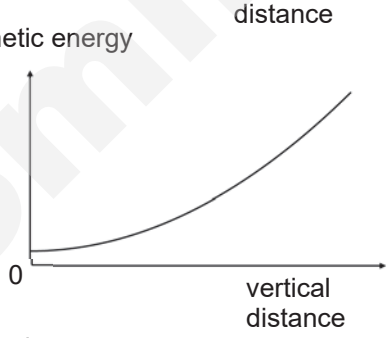


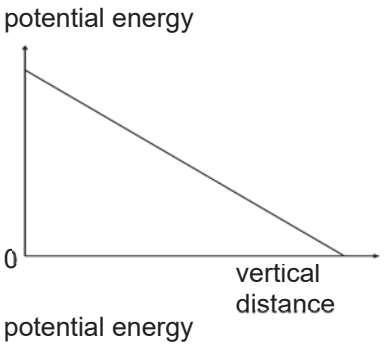
B



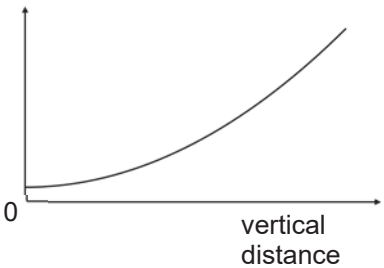


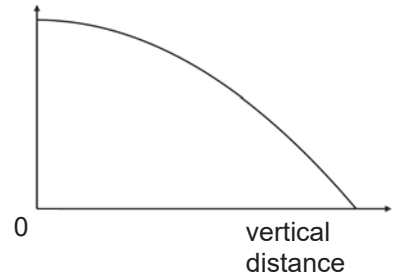
C





D





5 Box R of mass 5.00 kg rests on the smooth horizontal top of a trolley. Two strings

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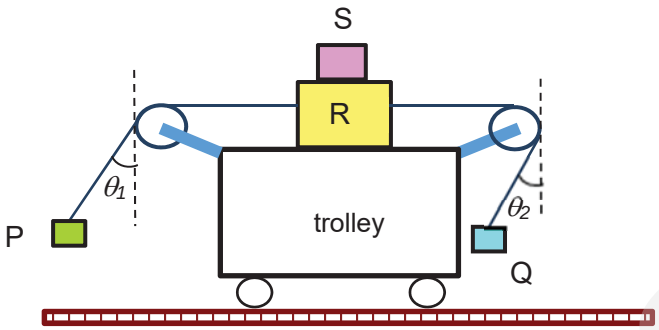
are attached to boxes P and Q of masses 2.00 kg and 3.00 kg respectively and the strings passes over two smooth pulleys. Box S of 0.50 kg mass rests on top of the box R. Frictional force *F* exist between the contact surfaces of R and S.



(Not drawn to scale)

There is no relative motion between the 4 boxes and the trolley, and the acceleration *a* of the system is 2.0 m s^{-2}.

Which of the following is correct?

	relationship between θ_1 and θ_2	direction of *F* on R
A	$\theta_1 > \theta_2$	left
B	$\theta_1 < \theta_2$	right
C	$\theta_1 > \theta_2$	right
D	$\theta_1 = \theta_2$	left

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6 Two identical smooth spheres X and Y have masses m and $3m$ with charges $+q$ and $+2q$ respectively. They are projected on a smooth horizontal plane with speeds $2v$ and v respectively towards each other and collided elastically. Fig. 6(a) shows a head-on collision. Fig. 6(b) shows an oblique collision.

Effects due to air resistance can be neglected.

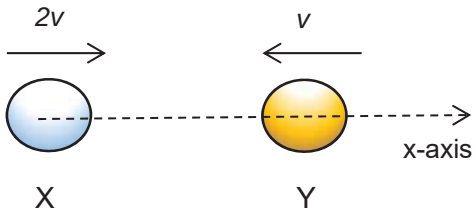

Fig. 6(a)

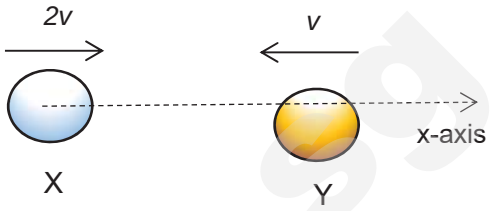

Fig. 6(b)

Which of the following is definitely correct?

A As the spheres are both positively charged, due to repulsive force on each, they will not collide.

B In the oblique collision, the total momenta after impact is not along the x-axis, and the total kinetic energies after impact is less than 3.5 mv^2.

C In the head-on collision, at the distance of closest approach, both the spheres are at rest.

D If the spheres are incompressible, the total momenta after impact is mv to the left, and the total kinetic energies is equal to 3.5 mv^2.

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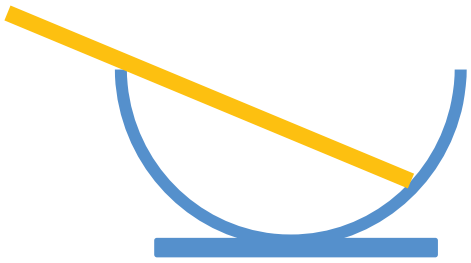
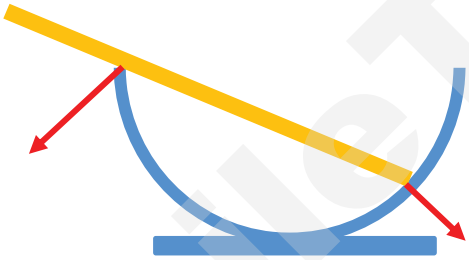
7 A uniform smooth rod is resting on a smooth empty hemispheric bowl as shown below.

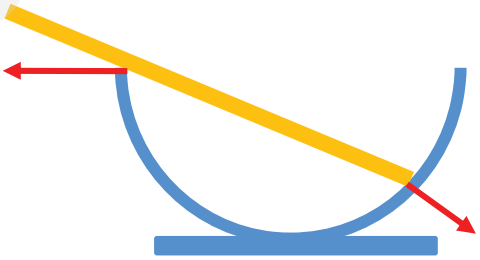


Which of the diagrams best shows the direction of the forces exerted by the rod on the bowl?

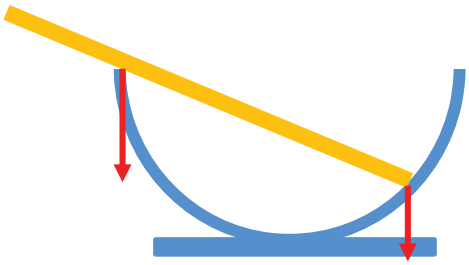
A



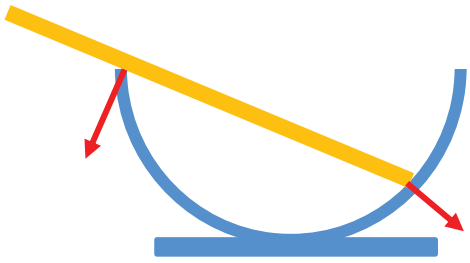
B



C



D



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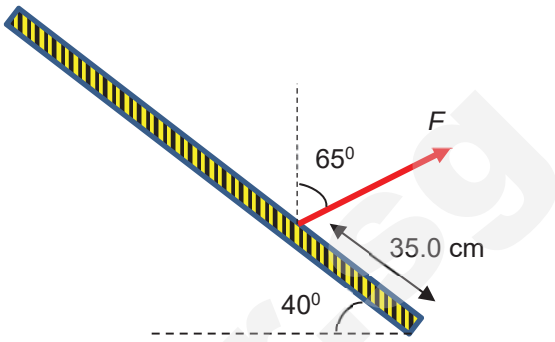
8 As shown in the figure below, a 2.0 m long uniform fishing rod has a mass of 126 g. With his right hand, the man grips the handle at a distance 35.0 cm from one end of the rod and exerts a force *F* at an angle 65° from the vertical. The fish is 500 g and hangs motionless at the other end or the rod.





Source: www.123RF.com

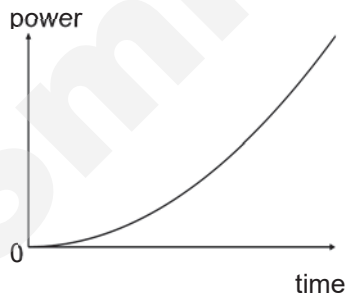
Which of the following is the value of *F*?

A 2.7 N **B** 3.0 N **C** 14.5 N **D** 26.7 N

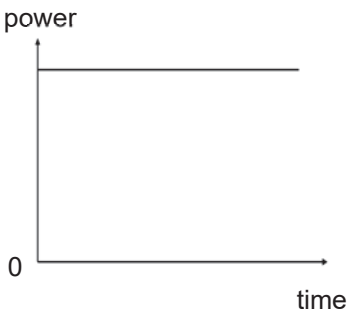
9 A constant force is applied on a box resting on a frictionless surface.

Which of the following graphs best represent the variation of power supplied with time?

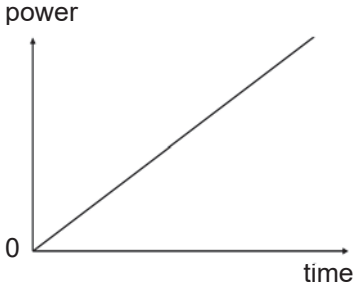
A



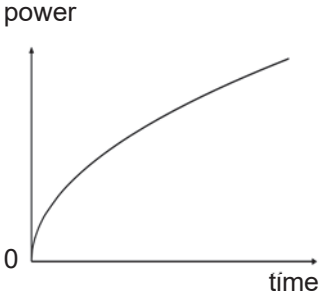
B



C



D



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10 The table lists four situations and the corresponding resultant forces acting on a man which provide him with a centripetal force during circular motion.

Which is incorrect?

	situation	resultant force on man
A	Man at the three o'clock position of a ferris wheel	Horizontal component of contact force of chair on man
B	Man onboard the international space station	Weight of man
C	Man on a motorbike during a turn	Frictional force of road on wheel
D	Man is upside down in a jet plane which is making a loop	Sum of normal contact force of chair on man and weight of man

11 In a system of Earth and Moon, which of the following is true?

A The common centre of mass of the system has net gravitational field strength of zero.

B The total gravitational potential is zero at the common centre of mass of the system.

C The change in potential energy in bringing a unit mass from infinity to a point between Earth and Moon is positive.

D The Moon orbits around a point near the centre of the Earth.

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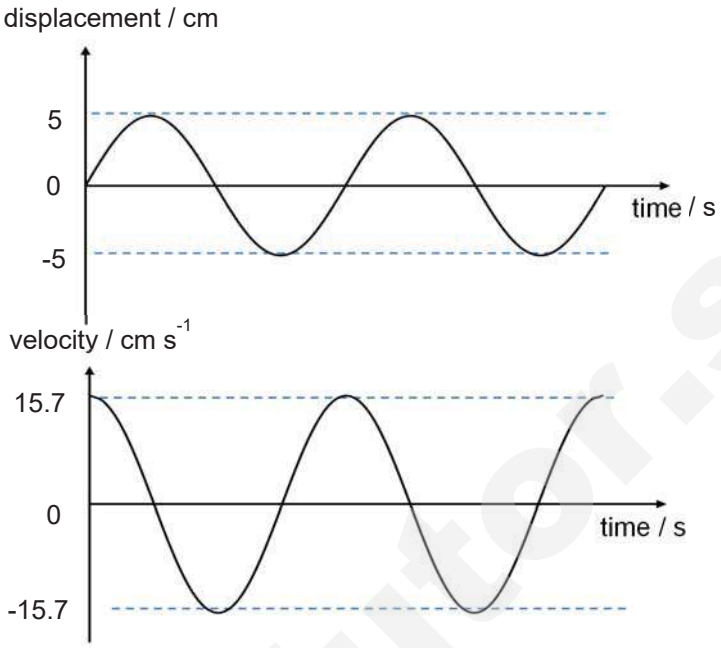
12 The graphs below show the variation of displacement and velocity with time of a body oscillating in simple harmonic motion.



Given that T is the period of the oscillation, what is the magnitude of the acceleration of the body at $\frac{T}{8}$ s?

A 0.7 cm s^{-2} **B** 34.8 cm s^{-2} **C** 49.3 cm s^{-2} **D** 55.5 cm s^{-2}

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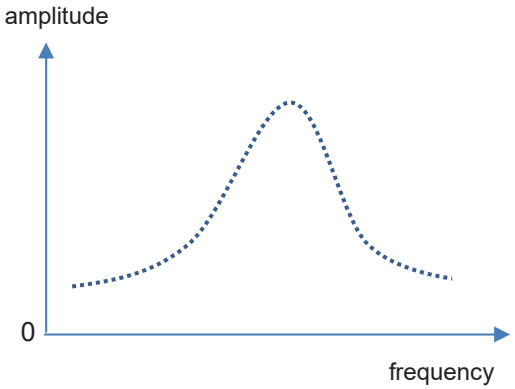
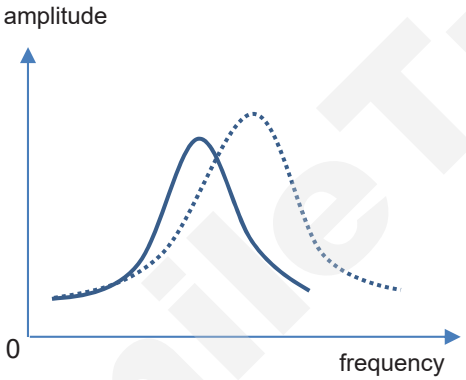
13 The graph below shows how the amplitude of a horizontal spring mass system varies with the driving frequency of an oscillator.



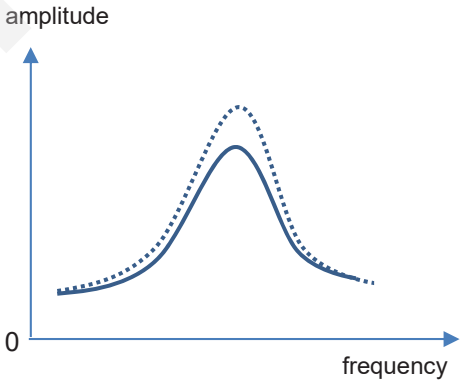
The spring is now replaced with a spring of higher spring constant.

Which graph best represents the new amplitude against frequency?

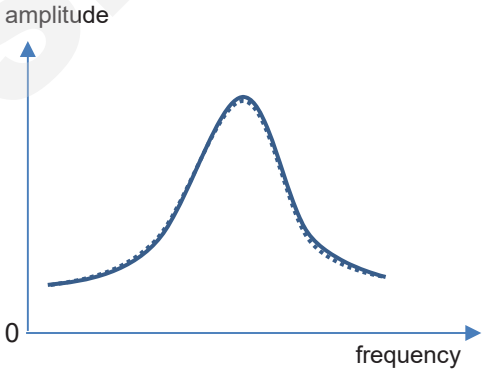
A



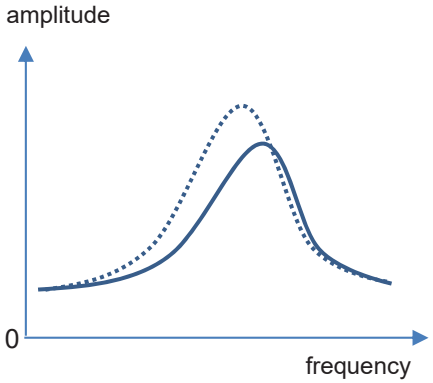
B



C



D



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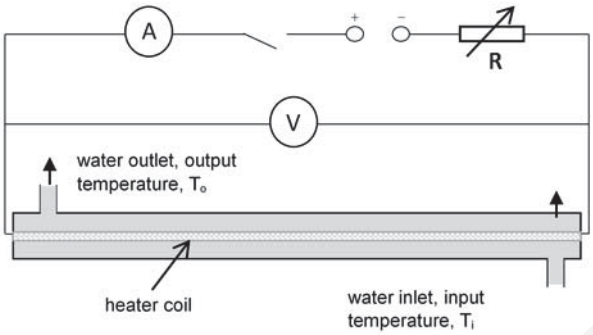
14 Water is passed through a heater coil in the setup as shown in order to determine its specific heat capacity.



The water flows over the heater coil at a constant rate. The output and input temperatures of the water at the water outlet and inlet are T_o and T_i respectively. A variable resistor R is connected to the circuit. The student conducted the experiment twice, each having a duration of 400 s.

Which of the following parameters must be kept constant for the two sets of experiment in order to account for the heat loss to the surrounding?

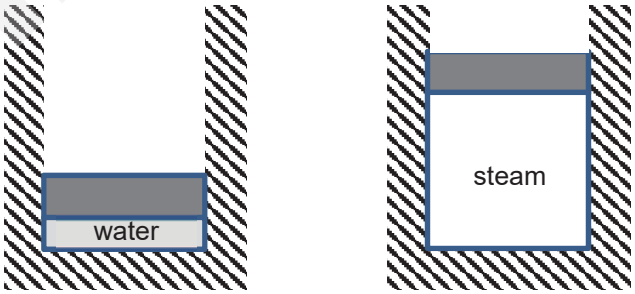
A T_o and T_i only

B R , T_o and T_i

C Flow rate of water between the outlets and R

D Flow rate of water between the outlets, T_o and T_i

15 Water at boiling point is converted into steam by a heating element placed within a well-insulated vessel with a moveable piston as shown.



Which of the following is correct?

	internal energy of the system	heat supplied to water	work done on steam
A	increase	is more than work done by steam	positive
B	increase	is more than work done by steam	negative
C	constant	is less than work done by steam	positive
D	constant	is less than work done by steam	negative

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16 Plane-polarised radio waves are transmitted by a vertical aerial. The amplitude of the waves is A when they reach a receiving aerial which is tilted from the vertical at an angle θ in the plane perpendicular to the direction of arrival.

The power delivered by the vertical aerial to the receiving aerial is proportional to

A $A\cos^2\theta$

B $A\cos\theta$

C $A^2\cos\theta$

D $A^2\cos^2\theta$

17 A string is set to vibrate between two fixed ends and a single antinode is observed between the fixed ends at a frequency of 225 Hz.

Which of the following is true when the same string is vibrating at 900 Hz?

A It has 3 more nodes than the original wave.

B No stationary wave is observed.

C Its wavelength is 4 times the original wavelength.

D Its wave speed has increased by 4 times.

18 To be able to resolve a grain of red sand of radius 50 μm, the maximum distance your eye can be positioned is 19 cm away from the grain.

What is the maximum distance for your eye to resolve a blue grain of sand?

A The distance remains the same

B The new distance is smaller than 19 cm

C The new distance is larger than 19 cm

D The blue grain of sand cannot be resolved

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19 A basic capacitor consists of two parallel conductive plates with opposite charges on each plate. A dielectric is a good insulator placed between them to prevent the charges from moving across to the other plate.

Fig. 19(a) shows a basic capacitor with a dielectric between the plates. Region M is within the dielectric.

Fig. 19(b) shows the same capacitor but the dielectric is replaced by a conductor placed closer to the negative terminal. The charges are unable to move across the plates. The mediums of P, Q and R are air, conductor and air respectively.

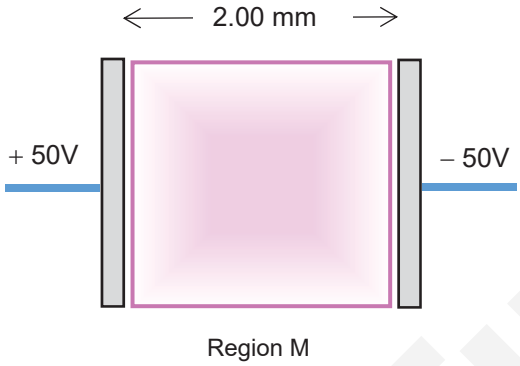

Fig. 19(a)

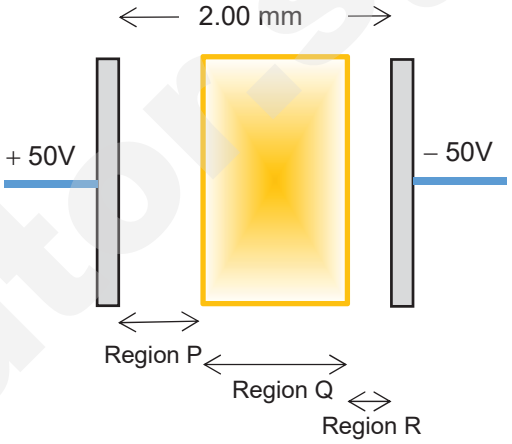

Fig. 19(b)

Which of the following is correct?

A Region P and Region R have the same electric field strength.

B The electric potential and electric field strength in Region Q are zero.

C Regions M, P and R have the same electric field strength, and the electric field strength at Region Q is zero.

D The electric field strength in Region Q is more than 5.00×10^5 N C^{-1}, but that in Region P and Region R are less than 5.00×10^5 NC^{-1}.

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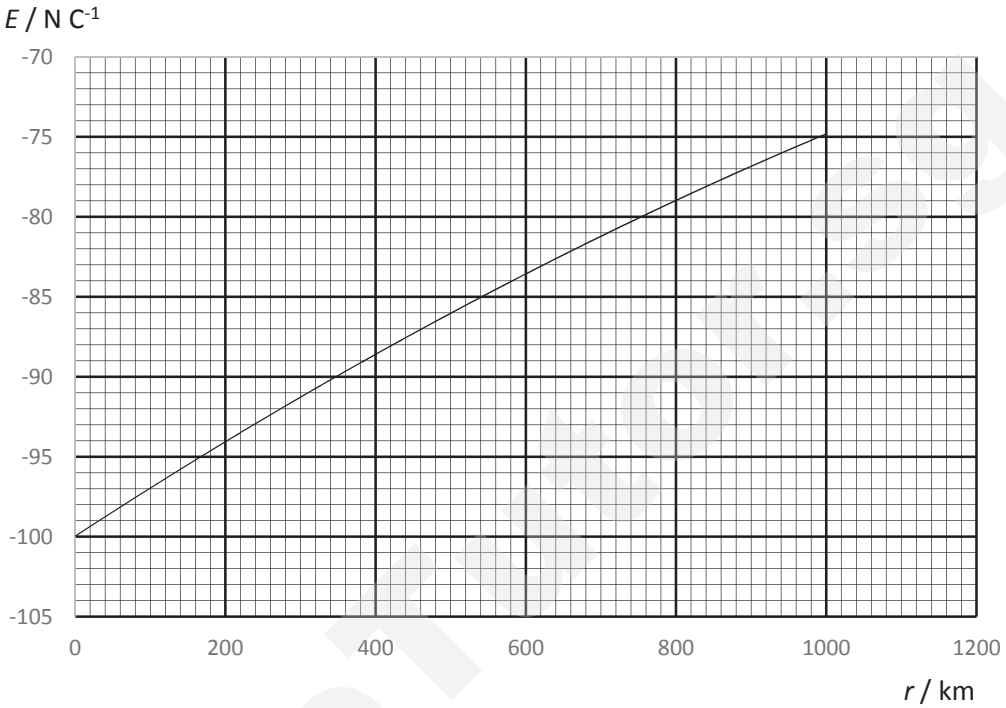
20 The Earth can be assumed to be a sphere of radius 6400 km where charges are uniformly distributed on the surface. The figure below shows the variation of the electric field strength E with the distance r from the surface of the Earth.

The electric field strength E on the surface of the Earth is - 100 N C^{-1}.



At 800 km above the Earth's surface, the electric potential is

A -2.25×10^{-5} V

B -7.50×10^{-5} V

C the gradient of the tangent of graph at r = 800 km

D the area between the graph and r axis from infinity to r = 800 km

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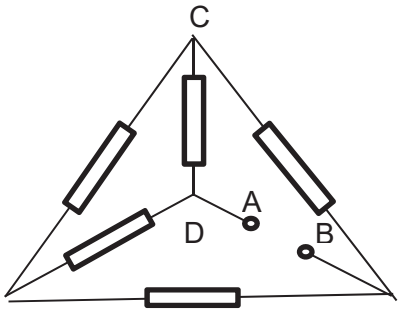
21 Five equal resistors, each of resistance R, are connected as shown.

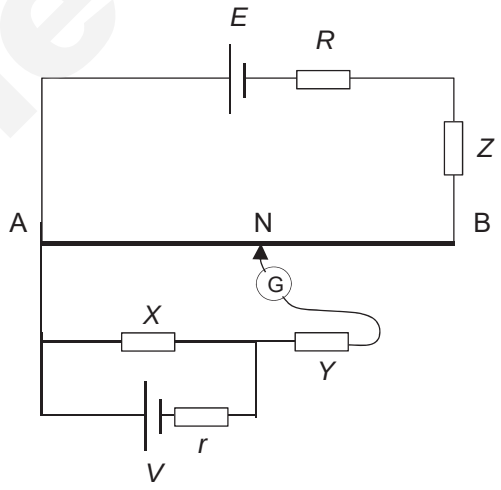


A battery of negligible internal resistance and emf V is connected between A and B.

What is the current flowing in CD?

A $\frac{V}{R}$ **B** $\frac{V}{2R}$ **C** $\frac{2V}{R}$ **D** $\frac{2V}{3R}$

22 A potentiometer containing a driver cell *E* of internal resistance *R* and resistor *Z* is connected to a circuit containing an unknown emf *V* of internal resistance *r* and resistors *X* and *Y* as shown.



In the experiment to determine *V*, a jockey is used to determine the null point on wire AB in order to obtain the length AN.

Which of the following will reduce the fractional uncertainty in the length AN?

A Decrease the resistance of *Y*

B Decrease the resistance of *X*

C Increase the resistance of AB

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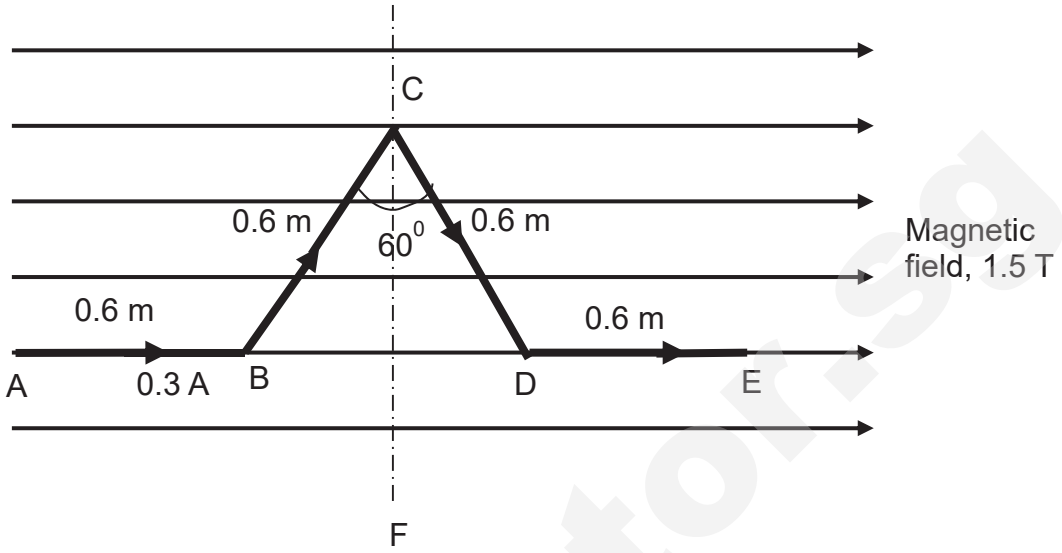
D Increase the resistance of *Z*

23 A current of 0.3 A flows in a conductor ABCDE that lies on the plane of the paper as shown in the figure below.



The conductor is inside a region of a uniform magnetic field having a magnetic field strength of 1.5 T. AB and DE are parallel to the magnetic field. Angle BCD is 60°. The lengths of segments AB, BC, CD and DE are 0.6 m each.

Which of the following describe the resultant force and resultant torque on the conductor?

	magnitude of resultant force	torque (view from the top)
A	0 N	Clockwise about CF
B	0 N	No resultant torque
C	0.47 N	Anti-clockwise about CF
D	0.47 N	No resultant torque

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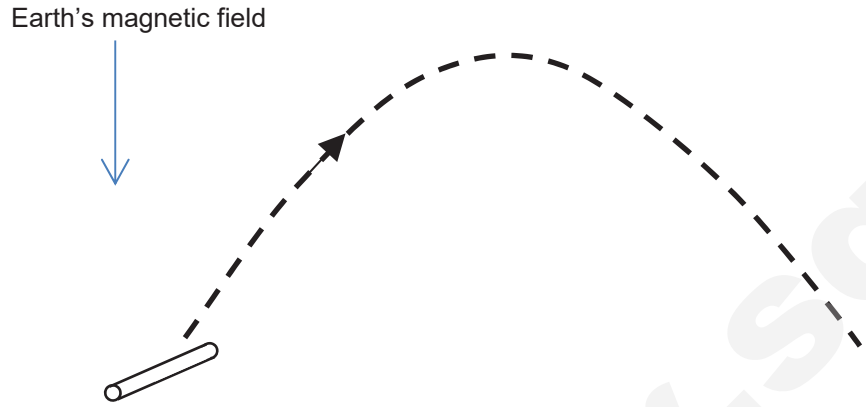
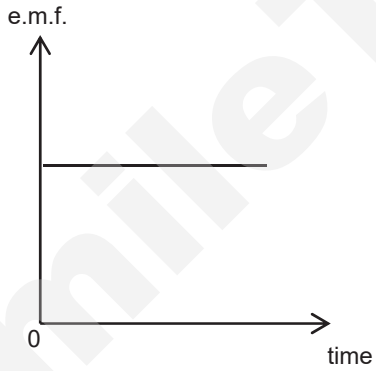
24 A metal rod moves in a parabolic path. Along its trajectory, the metal rod's long axis remains perpendicular to the earth's magnetic field. Air resistance is negligible.



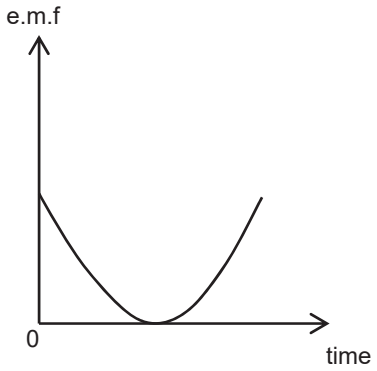
Assuming that the earth's magnetic field is pointing downwards and is uniform throughout the rod's trajectory.

Which of the following graphs show the variation of the e.m.f. induced between both ends of the rod with time?

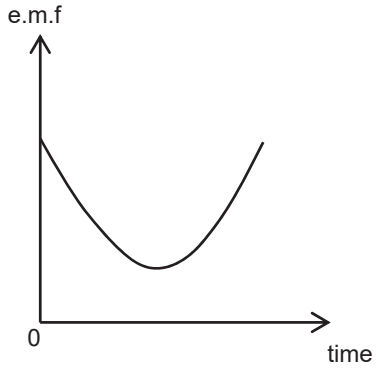
A



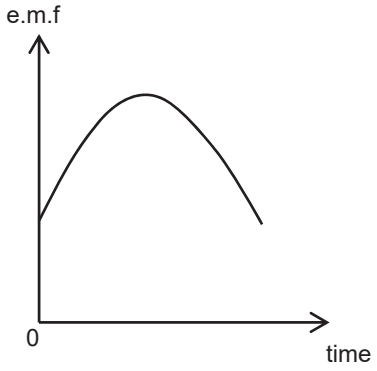
B



C



D



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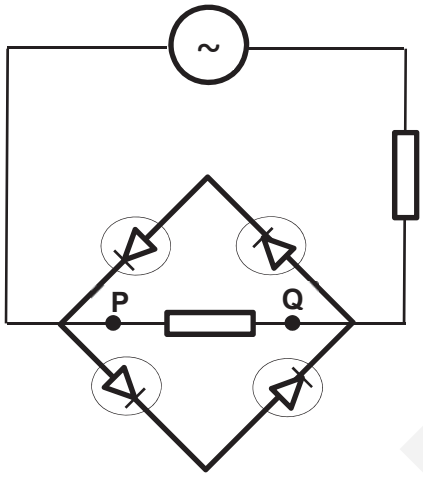
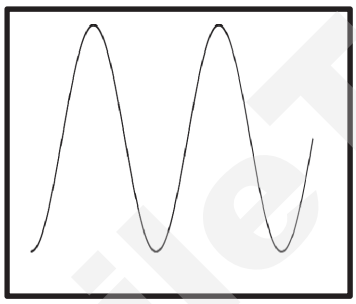
25 A sinusoidal alternating voltage source is applied to the circuit of diodes and resistors. The terminals P and Q are connected to a cathode-ray oscilloscope (C.R.O).

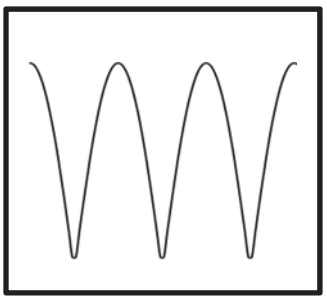


Which of the following traces would be seen on the C.R.O.?

A



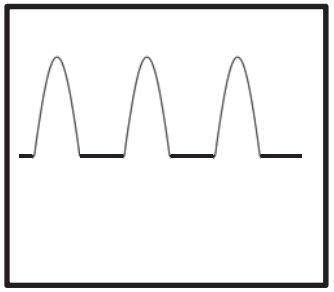
B



C



D



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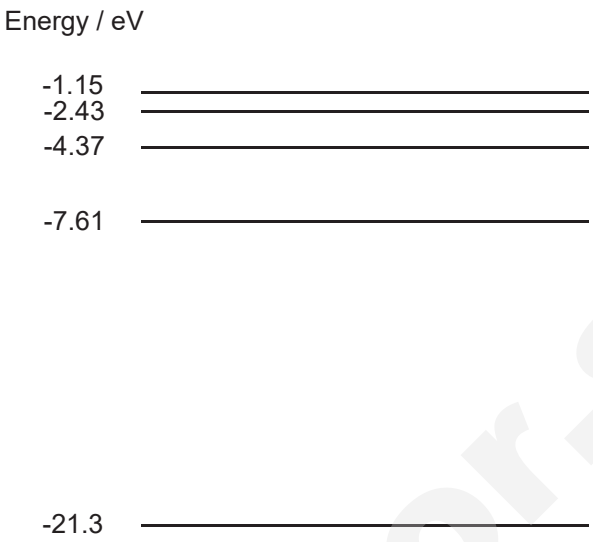
26 The lowest five levels of an atom are shown below.



A beam of electrons with energy 19.2 eV is incident on a cold gas of the atom.

Which of the following spectra will be produced?

A



B



C



D



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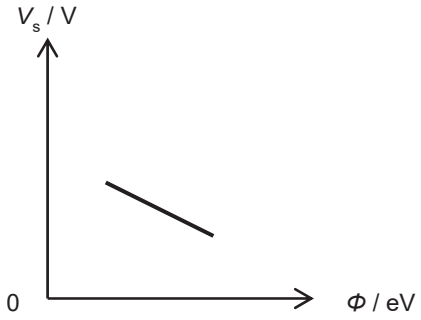
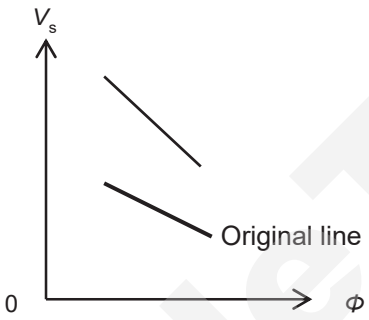
27 Electromagnetic radiation of a fixed wavelength is shone on different metals. The stopping potential for each metal is plotted against the work function of each metal to obtain the following graph.

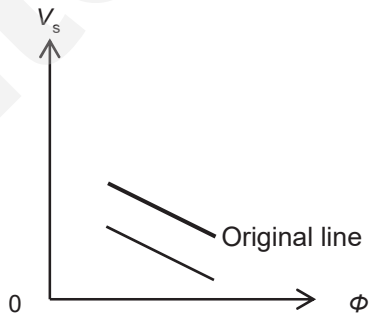


If both the wavelength and the intensity of the electromagnetic radiation is doubled, which of the following graphs reflect this change?

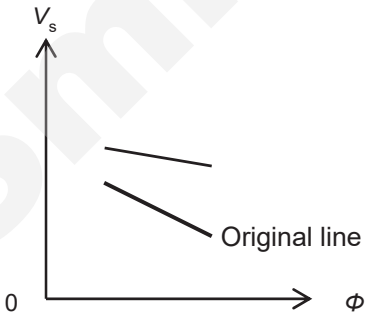
A



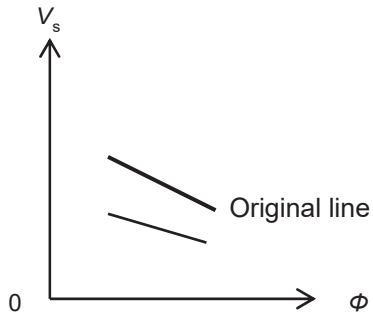
B



C



D



28 A beam of electrons and a beam of protons are accelerated across the same potential difference. They each then undergo diffraction through a crystal lattice to determine their de Broglie wavelength. The de Broglie wavelength of the electron is found to be 3.9×10^{-9} m.

What is the theoretical de Broglie wavelength of the proton?

A 2.1×10^{-12} m **B** 9.1×10^{-11} m **C** 3.9×10^{-9} m **D** 1.7×10^{-7} m

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29 A fluorine-18 (${}^{18}_{9}F$) nucleus can capture a proton (p), producing a neon-19 (${}^{19}_{10}Ne$) nucleus as the product.

$$ {}^{18}_{9}F + p \rightarrow {}^{19}_{10}Ne $$

The mass defect of ${}^{18}_{9}F$ and ${}^{19}_{10}Ne$ are 0.147 12u and 0.153 98u respectively.

What is the energy change associated with this reaction?

A 930 MeV released

B 930 MeV absorbed

C 6.5 MeV released

D 6.5 MeV absorbed

30 The ratio of ^{14}C:^{12}C in living things is fixed when they are alive but decreases after death because of the radioactive decay of ^{14}C. A 10.0 g sample of wood cut from a live tree is measured to have an activity of 120.00 min^{-1}.

If a 1.0 g sample of a 3300 year old wooden relic is found to have an activity of 8.05 min^{-1}, what is the half-life of ^{14}C?

A 847 years **B** 1320 years **C** 5730 years **D** 8920 years

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H

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JC2 Physics Preliminary Examination
Higher 2

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PHYSICS **9749**
Paper 2 Structured Questions 11 August 2017
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Name and Index number in the spaces on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

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1	/ 7
2	/ 10
3	/ 9
4	/ 12
5	/ 11
6	/ 12
7	/ 19
Total	/ 80

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DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/^oC + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer all questions

1 **(a)** Box A rest on a smooth slope and is connected to Box B using a light inextensible string as shown in Fig 1.1. Box A and Box B have masses of 10 kg and 3 kg respectively. The setup is initially at rest.

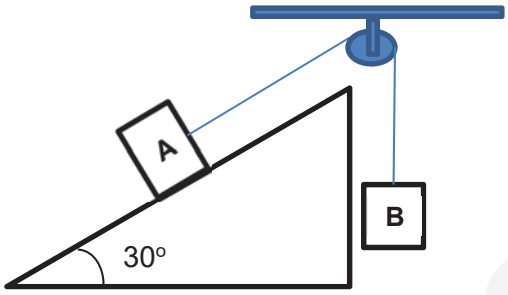

Fig 1.1

(i) Determine the initial acceleration of Box A.

Acceleration = ... m s^{-2} [3]

(ii) The string subsequently snapped. Box B is now 2.0 m above the ground and has an upward velocity of 0.5 m s^{-1} as shown in Fig 1.2.

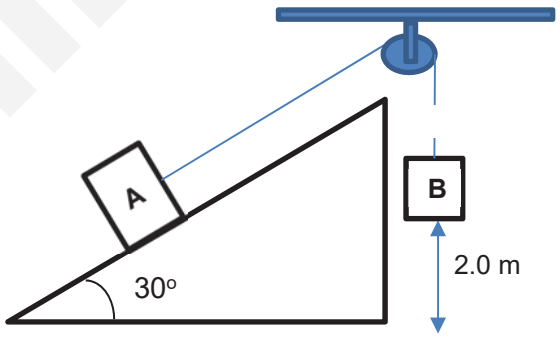

Fig 1.2

Determine the velocity of Box B when it hits the ground.

Velocity = ... m s^{-1} [2]

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(b) By considering the work done by the force(s) acting on a ball, derive the equation, $E_G = mgh$, where E_G is the change in the gravitational potential energy of a mass m moved through a vertical distance h near the earth's surface.

[2]

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2 The kinetic theory of gases deals with how molecular movement causes pressure to be exerted by a gas. The pressure of a gas is due to the elastic collision of the gas molecules with the walls of a container.

A single molecule of mass m is travelling with speed u directly towards a wall of a cubical box of sides L is as shown in Fig. 2.1.

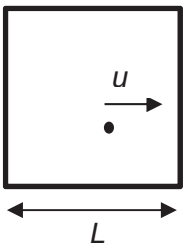

Fig. 2.1

(a) Express the following in terms of L, m and u.

Momentum to the right before collision with wall = mu

Momentum immediately after an elastic collision = ……

Time between collisions with the same wall = ……

Number of collisions with this wall per unit time = ……

Rate of change of momentum of the molecule = ……

Average force on the wall = …… [2]

(b) The pressure p of an ideal gas which contains N molecules with different speeds in a container of volume V is given by

$$pV = \frac{1}{3}Nm < c^2 >$$

where $<c^2>$ is the mean square speed of the molecules.

(i) State the assumption regarding the type of collision between gas molecules.

…… [1]

(ii) The deduction of the relationship stated in **(a)** does not involved collisions between the gas molecules. In practice, gas molecules will collide with one another.

Using your answer in **(b)(i)**, explain why the collision among the molecules do not have an impact on the pressure.

……

……

……

……

…… [2]

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(c) Using the expression in **(b)** and the ideal gas equation, show that the average kinetic energy of an ideal gas molecule is proportional to the thermodynamic temperature T.

[1]

(d) The first law of thermodynamics when applied to an ideal gas can be expressed as

$$\Delta U = Q + W$$

where ΔU is the increase in internal energy, Q is the heat supplied to the gas and W is work done on the gas.

(i) The gas undergoes a process from state A to state B in such a way that ΔU is 0 as shown in Fig. 2.2.

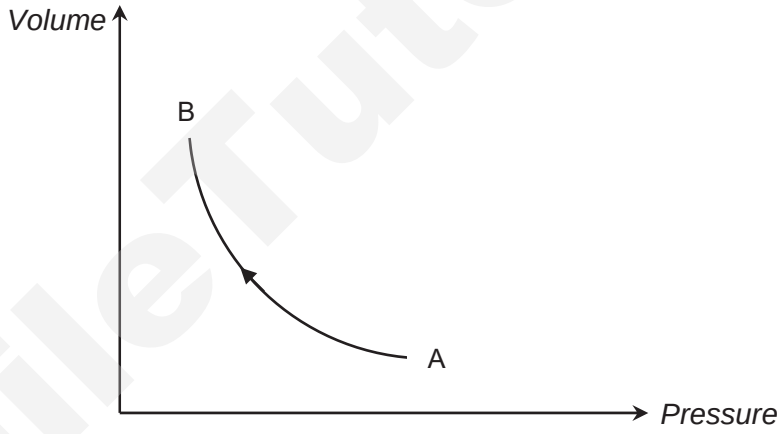

Fig. 2.2

1. Shade in Fig. 2.2 the area that numerically represents the heat exchange between the gas and its surroundings. [1]

2. Deduce the difference in the product of pressure and volume of the gas at both state A and state B.

……

…… [1]

(ii) The change in volume in **(d)(i)** takes place slowly. State and explain the changes to the mean square speed of the gas molecules if the change in volume takes place very quickly instead.

……

……

…… [2]

[Turn over

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3. (a) An electron passes through a region of uniform magnetic field of flux density, B as shown in Fig 3.1.

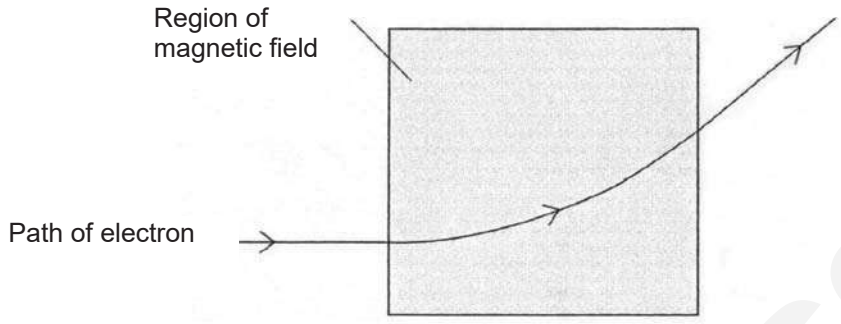

Fig 3.1

(i) Deduce the direction of the uniform magnetic field

…….. [1]

(ii) Suggest how an electric field of strength E may be applied to allow the electron to pass through the region undeflected.

……

……

…… [1]

(iii) Hence or otherwise, show that the velocity v, for the electron to pass through the fields undeflected is given by $v = \frac{E}{B}$

[1]

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(b) The electron of mass m_e and charge q subsequently enters into another uniform magnetic field. The magnetic field is directed along the positive x-axis and has a field strength of B. The electron, traveling with a speed v and kinetic energy of 10 eV, enters the field along a direction that makes an angle of $\theta = 60°$ with the x-axis and is perpendicular to the z-axis as shown in Fig. 3.2.

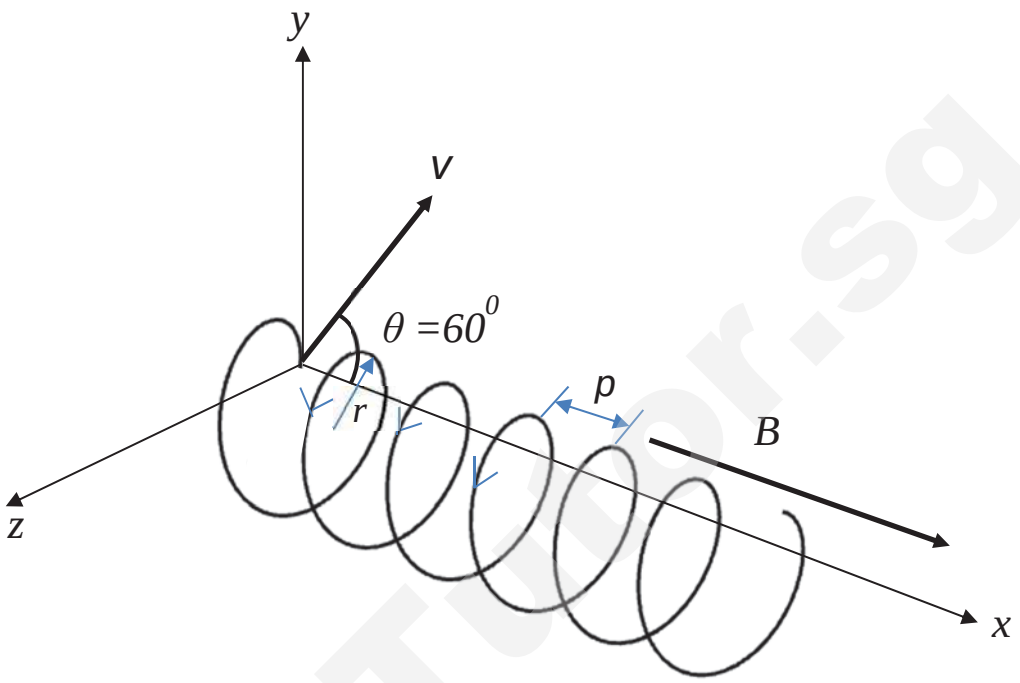

Fig. 3.2

(i) Show that v is 1.87 x 10^6 m s^{-1}.

[1]

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(ii) The pitch p is defined as the distance along the x-axis between 2 successive helical paths.

Show that p is given by the following expression:

$$p = \frac{2\pi m_e v \cos\theta}{qB}$$

[3]

(iii) The magnitude of B is given to be 5.0 x 10^{-4} T. Hence or otherwise, determine distance that the electron will travel in the x-direction after it has completed 3 successive helical paths.

Distance = …….. m [2]

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4 **(a)** Define *electric field strength*.

……

……

……

…… [2]

(b) A hypothetical model of a planet of radius of 6400 km is illustrated in Fig. 4.1, consists of negative charges $-Q$ uniformly distributed on the surface, and a positive point charge $+Q$ at the centre. The planet is neutral.

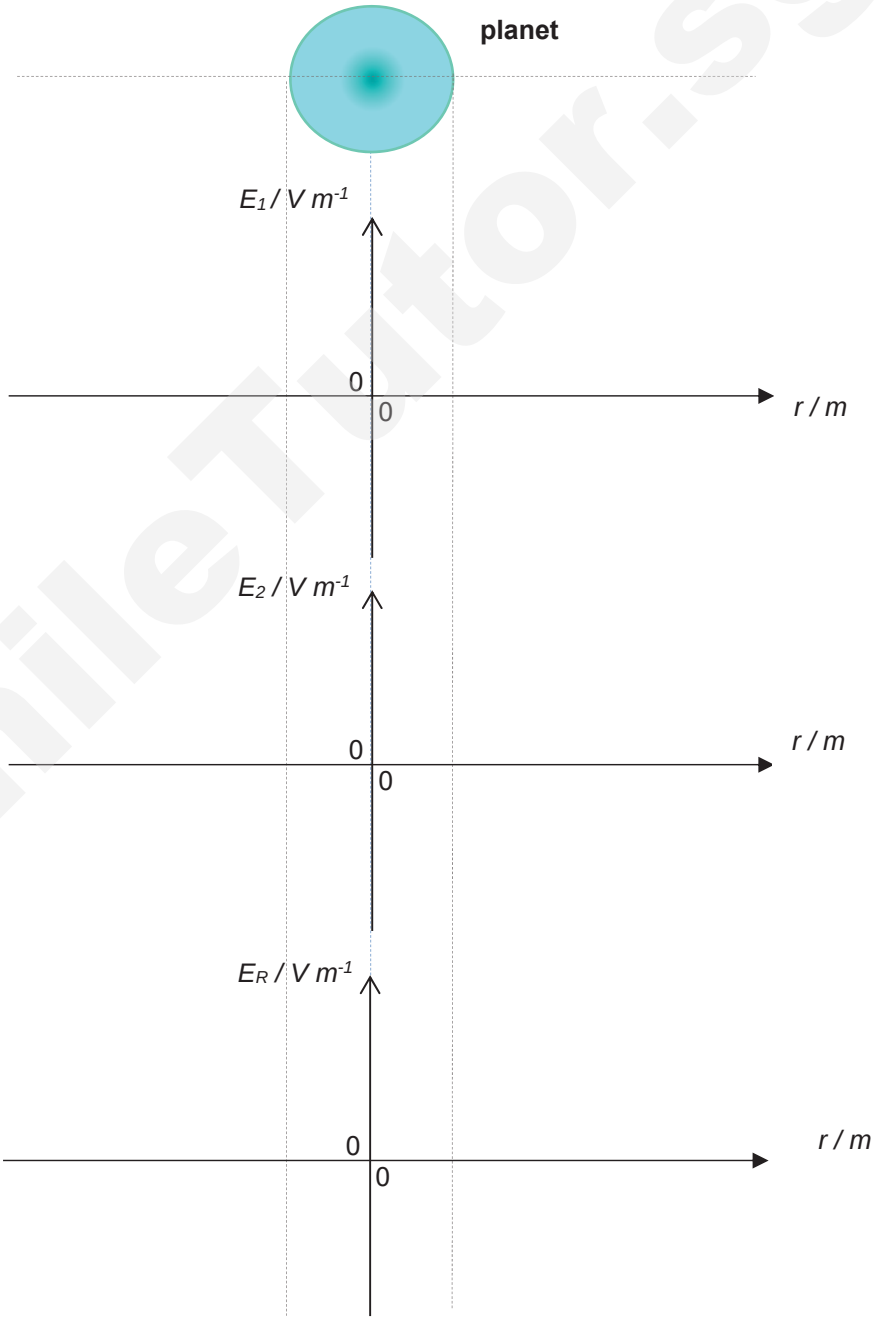

Fig. 4.1(a)

Fig. 4.1(b)

Fig. 4.1(c)

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Sketch graphs of the electric field strength E against distance r, due to the

(i) negative charges $-Q$ on the surface only on Fig. 4.1(a)

(ii) positive point charge $+Q$ at the centre only on Fig. 4.1(b)

(iii) both negative and positive charges on Fig. 4.1(c)

[3]

(c) A second hypothetical model suggests that both a planet and its moon are negatively charged and the charges reside on their surfaces only. The diameter of the planet, D, diameter of the moon, d, and distance between the planet and moon, L, are given by the equations below

$$L = 10^5 D, \quad \text{and} \quad D = 10^5 d,$$

and the planet and its moon have the same density.

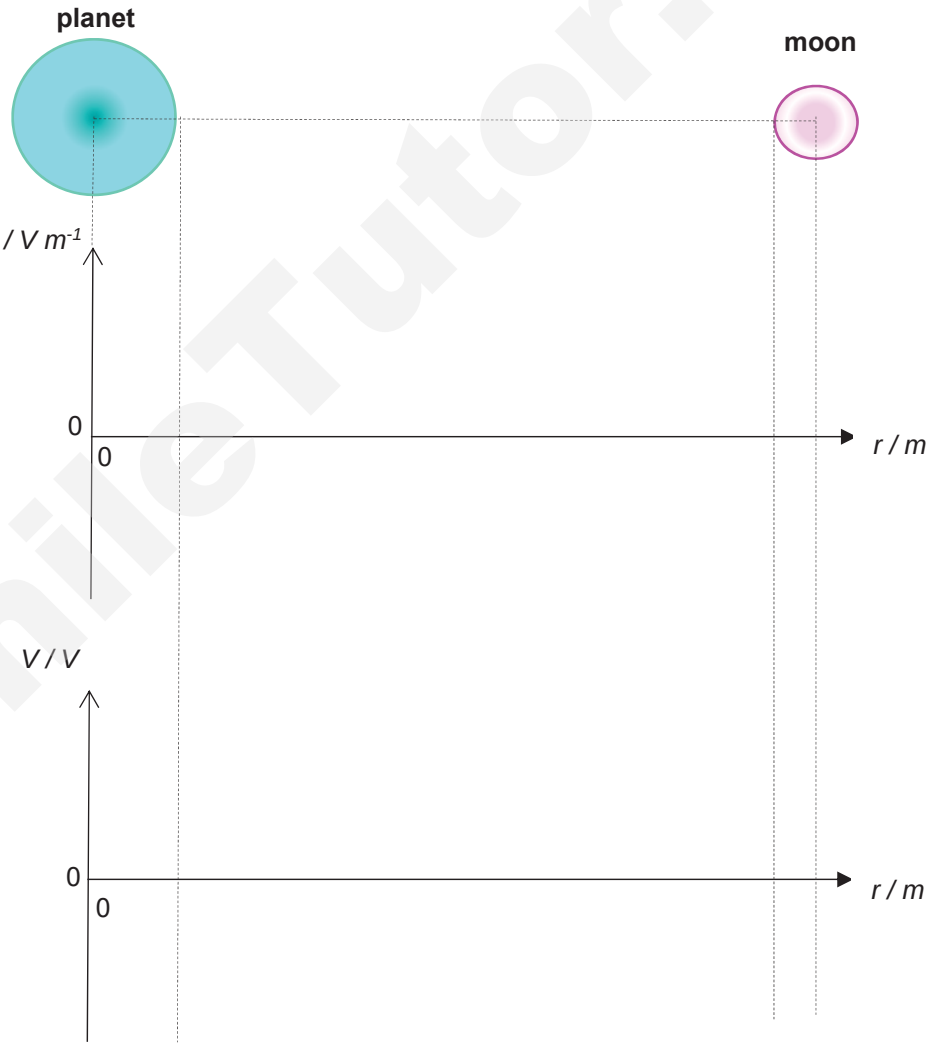

Fig. 4.2(a)

Fig. 4.2(b)

For the planet and its moon, sketch graphs of the

(i) resultant electric field strength E in Fig 4.2(a), and

(ii) resultant electric potential V in Fig 4.2(b)

against distance r from the centre of the planet. Graphs do NOT need to be drawn exactly to scale. [3]

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(d) A beam of electrons with velocity *v* enter the centre of a uniform electric field established between 2 charged plates as shown in Fig. 4.3. The plates are 5.0 cm long and 4.0 mm apart and has a potential difference of 80 V.

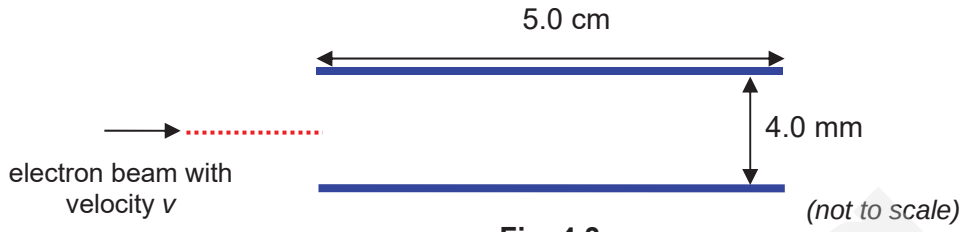

Fig. 4.3

Determine the minimum speed of the electrons such that they can emerge from the charged plates.

Minimum speed = …….. m s^{-1} [4]

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5 **(a)** The graph in Fig. 5.1 shows the spectrum of the visible light coming from a bright star. These lines correspond to the Balmer series for hydrogen gas which are transitions from higher energy levels to level $n = 2$.

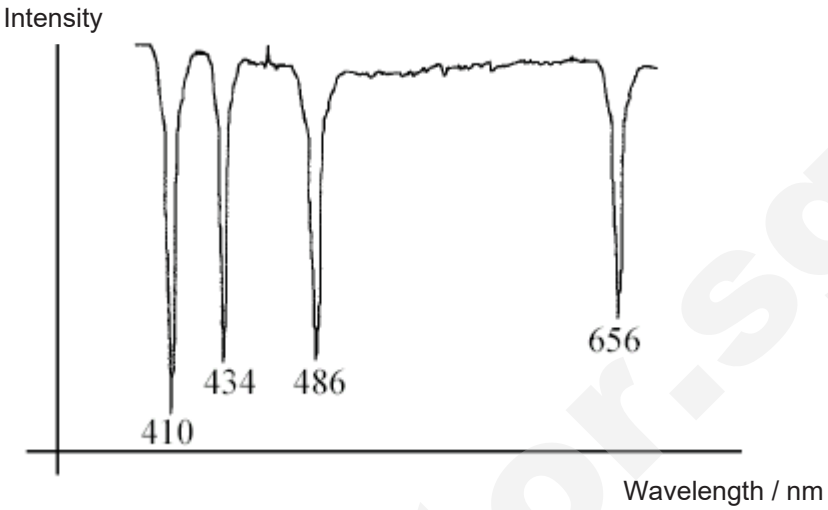

Fig. 5.1

(i) State and explain the type of spectrum shown in Fig. 5.1.

……

……

…… [2]

(ii) Given that the energy of level $n = 2$ is -5.44×10^{-19} J, calculate the energy of level $n = 3$, E_3.

E_3 = …… eV [3]

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(b) Ultra-violet radiation of wavelength 184 nm is shone on a cathode within a vacuum tube as shown in Fig. 5.2 and photoelectrons are observed to be emitted.

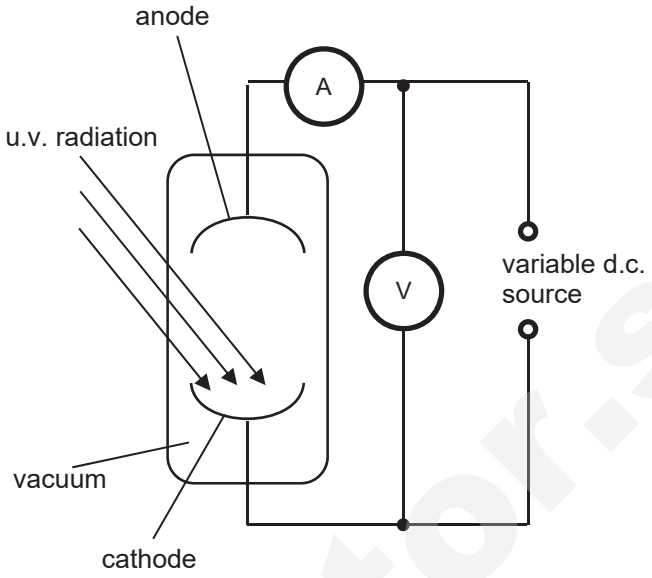

Fig. 5.2

The potential difference across the cathode and anode is varied and the corresponding value of the current is measured with the ammeter. Fig. 5.3 shows the relationship between these two quantities.

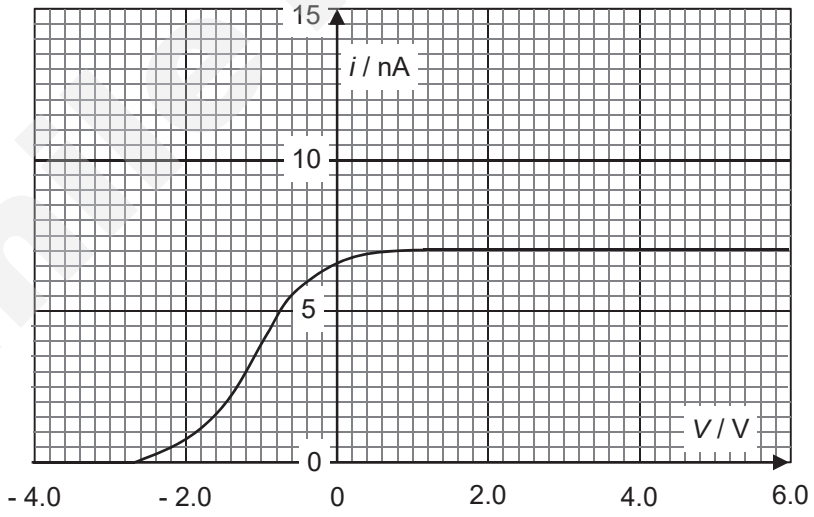

Fig. 5.3

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(i) The presence of a threshold frequency is an evidence for the particulate nature of electromagnetic radiation.

Explain why the wave nature of electromagnetic radiation does not support this observation.

……..

……..

……..

……..

…… [2]

(ii) Determine the work function of the cathode.

Work function = …….. J [3]

(iii) The cathode is replaced with a metal with **lower** work function.

Sketch, on Fig. 5.3, the new *i*-*V* graph.

[1]

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6 **(a)** When a star has fused all its hydrogen to helium, it will start to fuse helium into carbon through the following reaction.

$$^{4}_{2}He + {}^{4}_{2}He + {}^{4}_{2}He \rightarrow {}^{12}_{6}C$$

(i) The binding energy per nucleon of helium and carbon are given in the table below.

	Binding Energy per nucleon / MeV
$^{12}_{6}C$	7.680
$^{4}_{2}He$	7.074

Calculate the energy produced from this fusion reaction.

Energy produced = …… MeV [2]

(ii) A star in the milky way gives off energy at a rate of 2.75 x 10^{26} W solely due to the fusion of helium in its core.

Calculate the number of helium nuclei *N*, that reacted in one second.

N = …… s^{-1} [3]

[Turn over

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(b) Beta decay provides evidence for the existence of neutrinos. One such example is the spontaneous decay of carbon-14 into nitrogen-14. Neutrinos, ν, which have negligible mass and no charge, are emitted in the process.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + e + \nu$$

In beta decays, the electrons emitted has a range of possible velocity. Explain how this can be used to predict the existence of neutrinos.

……

……

……

……

……

……

……..…… [3]

(c) Radon ($^{220}_{86}Rn$) decays spontaneously with a half-life of 56 s to form polonium ($^{216}_{84}Po$). During this decay, an alpha particle and a gamma ray photon are emitted.

$$^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + {}^{4}_{2}\alpha + \gamma$$

A 2.0 g sample of radon is left to decay. The mass of one mole of radon and polonium are 220.0 g and 216.0 g respectively.

Determine the mass of the sample after 5.0 minutes.

Mass = …… g [4]

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7 Renewable energy is energy that is generated from natural processes that are continuously replenished. This includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This energy cannot be exhausted and is constantly renewed.

While raw forms of energy are both free and practically infinite, the equipment and materials needed to collect, process, and transport the energy to the users can be costly. Table 7.1 compares the average electricity cost in dollars per kilowatt-hour for both non-renewable and alternative fuels in new power plants.

Power Plant Type	Cost $/kW-hr
Coal	$0.095-0.15
Natural Gas	$0.07-0.14
Nuclear	$0.095
Wind	$0.07-0.20
Solar PV	$0.125
Solar Thermal	$0.24
Geothermal	$0.05
Biomass	$0.10
Hydro	$0.08

Source: Adapted from US Energy Information Administration

Fig 7.1

(a) With reference to Fig 7.1, suggest

(i) why geothermal energy is not widely adopted even though it is the cheapest.

……

……[1]

(ii) a possible factor that may cause the cost of some renewable energy, such as wind energy, to vary across a range.

……

……[1]

(iii) one advantage that conventional energy sources has over renewable energy.

……

……[1]

[Turn over

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Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

(b) (i) Using momentum consideration, explain how the wind is able to turn the blades of the wind turbine.

……

……

……

……

……

……

……[3]

(ii) The average size of a wind turbines being manufactured today can be more than a hundred metres tall with blades of about 50 metres length. If the average speed of the wind before it enters the wind turbine is 13.5 m s^{-1} and is 12.8 m s^{-1} after it exits the wind turbine, determine the maximum power that the wind turbine can generate.

You may assume that the density of air before it enters the wind turbine is 1.23 kg m^{-3}.

Maximum power = …… W [3]

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(iii) A mayor wanted to build a wind farm to supply the energy needs of his town of 2,000 households. The average monthly (30 days) household consumption of each household is 4,100 kWh and the wind turbine can be assume to be running at an average of 22% of its maximum output power for the entire year.

Determine the minimum number of wind turbines that are needed to be built.

Minimum number of wind turbine needed = …… [3]

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[Turn over

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Many innovations had evolved in the area and wind lens is one of them. Wind lens, as shown in Fig 7.2, is a type of wind power system consisting of a simple brimmed ring structure that surrounds the rotor causing greater wind to pass through the turbine. As a consequence, the turbine's efficiency of capturing energy from the wind increases and a wind lens turbine can generate 2 to 5 times the power of an existing wind turbine, as shown in Fig 7.3, given at the same rotor diameter and incoming wind speed.



Fig 7.2



Fig 7.3

Source: Research Institute for Applied Mechanics, Kyushu University

Fig 7.4 shows a simple schematic of a wind lens attached to a turbine while Fig 7.5 show the power generated against wind speed of a normal wind turbine and one that has an attached wind lens.

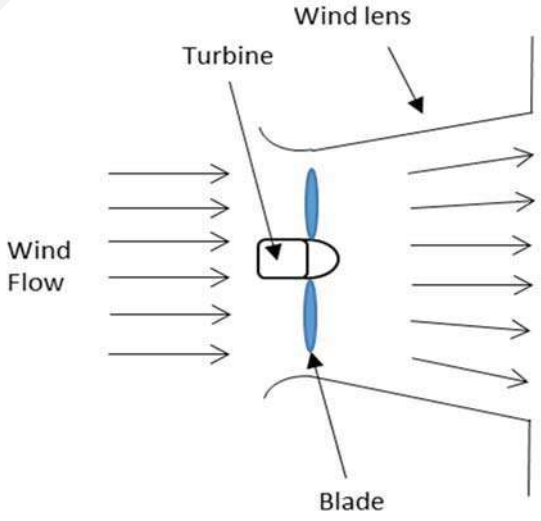

Fig 7.4

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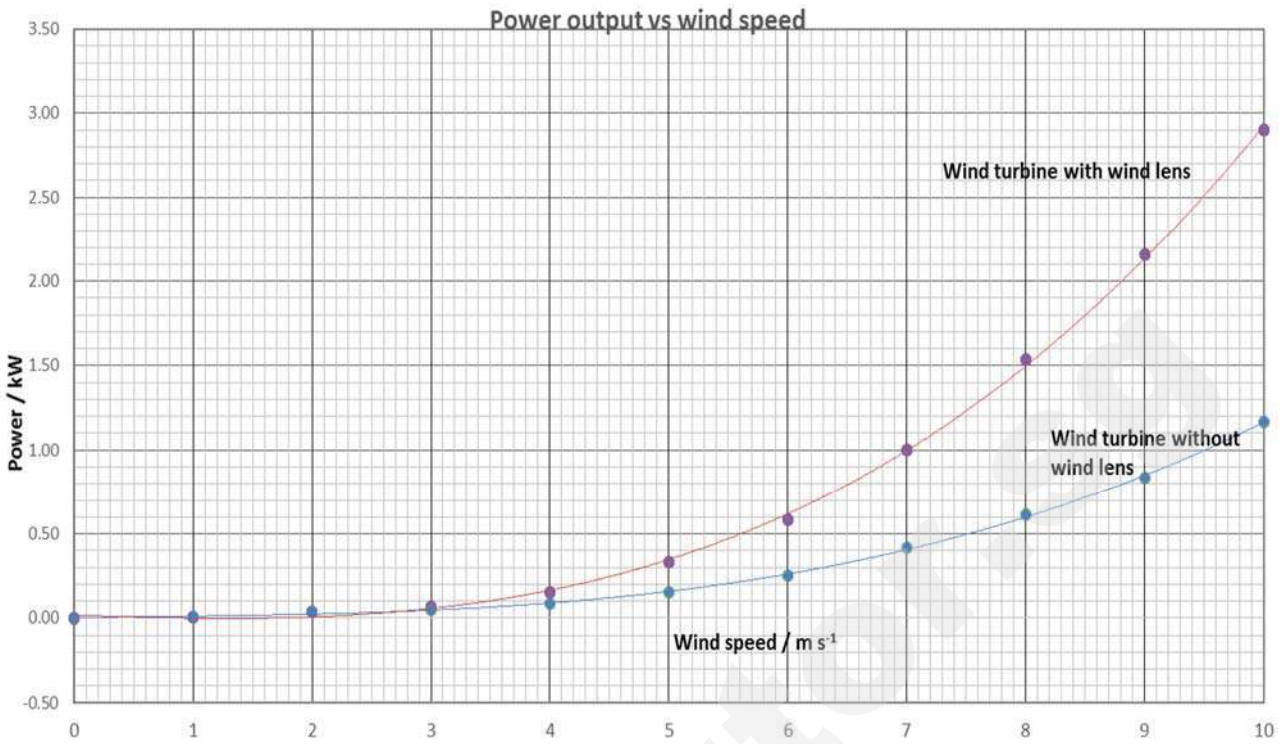

Source: Adapted from Research Institute for Applied Mechanics, Kyushu University

Fig 7.5

(c) (i) Suggest a possible reason why the use of a wind lens allow the wind turbine to generate a higher power output.

……

……

……

……

……[2]

(ii) Using Fig 7.5, determine the additional power that can be can be generated by a wind turbine with wind lens compared to a wind turbine without a wind lens when the wind speed is 9.5 m s^{-1}.

Additional Power = …… W [2]

[Turn over

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(iii) Using Fig 7.5, determine the relationship between the power generated by a wind turbine without a wind lens and the wind speed.

[3]

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Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

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PHYSICS **9749/03**
Paper 3 Longer Structured Questions 17 August 2017
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your Name and Index number in the spaces on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** questions only

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Section A	
1	/ 10
2	/ 11
3	/ 10
4	/ 8
5	/ 10
6	/ 11
Total	/ 60
Section B	
7	/ 20
8	/ 20
Grand Total	/ 80

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DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** questions in the spaces provided

1 (a) It is suggested that the mass flow rate Q of grains through a hopper can be given by

$$Q = C\rho\sqrt{g}(D - kd)^{3/2}$$

where C and k are constants, ρ is the density of the grains, D is the diameter of the aperture of the hopper, d is the diameter of the circular grain and g is the acceleration due to free fall.

Determine the units of C and k in terms of the SI base units

units of k = ……..

units of C = …….. [3]

(b) A student wants to determine the density of a solid circular disc by measuring its dimensions with a ruler and its weight using a mass balance. He recorded his readings as follows.

Diameter of the circular disc = (3.6 ± 0.2) cm
Height of the circular disc = (2.4 ± 0.2) cm
Mass of the circular disc = (212.5 ± 0.1) g

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(i) Determine a value for the density of the disc with its associated uncertainty.

density = …… ± ……..…… kg m^{-3} [4]

(ii) Explain which variable has the largest impact on the uncertainty of the density.

……..…

……..……..[1]

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(c) A glider is at the location as indicated in Fig. 1.1 and is flying with a speed of 3 m s^{-1} in the direction 30° East of North. A wind of speed of 5 m s^{-1} is blowing towards the direction of 35° West of North.

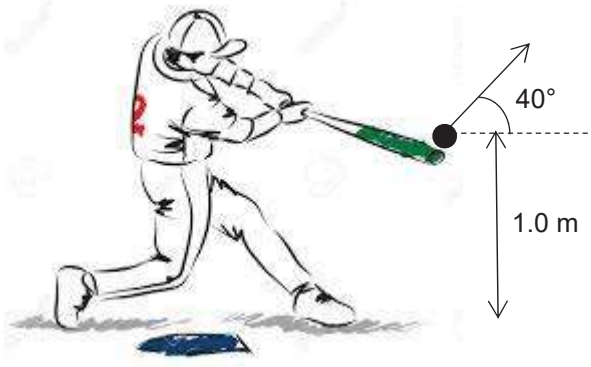
By drawing a scale diagram, indicate on Fig 1.1, the location of the glider after 2 seconds. State your scale for your diagram clearly.



Fig. 1.1

[2]

2 A baseball player strikes a baseball with his bat. At the point where the baseball loses contact with the bat, it is 1.0 m above the ground and is travelling with a speed of 38.0 m s^{-1} and makes an angle of 40° with the horizontal as shown in Fig. 2.1. Air resistance can be neglected.



Source: www.123rf.com

Fig. 2.1

(a) Determine

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(i) the maximum height above the ground that the baseball can reach.

Height = ... m [3]

(ii) the speed of the baseball when it hits the ground.

Speed = ... m s^{-1} [2]

(iii) If air resistance is not negligible, sketch on Fig. 2.2, a well-labelled graph of the variation of its height above the ground with horizontal distance for the baseball from the start till it hits the ground.

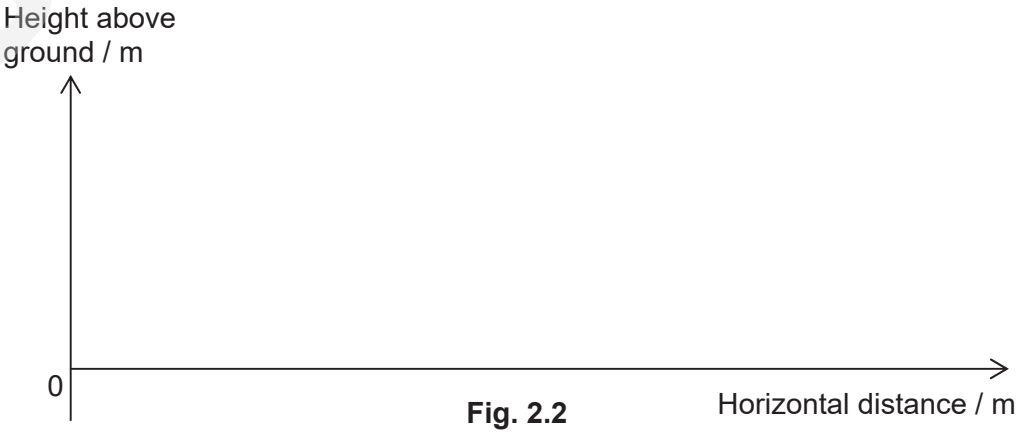

Fig. 2.2

[2]

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(b) An outfielder is a player in the opposing team who will try to catch the baseball using his gloves before it hits the ground. When the baseball first loses contact with the bat, the outfielder is 25.0 m away and the baseball is moving in his direction as shown in Fig. 2.3. His outstretch arm is 1.0 m above the ground.

(i) Determine the average speed that he has to start running from this instant in order to catch the baseball if he remains in this outstretch posture.

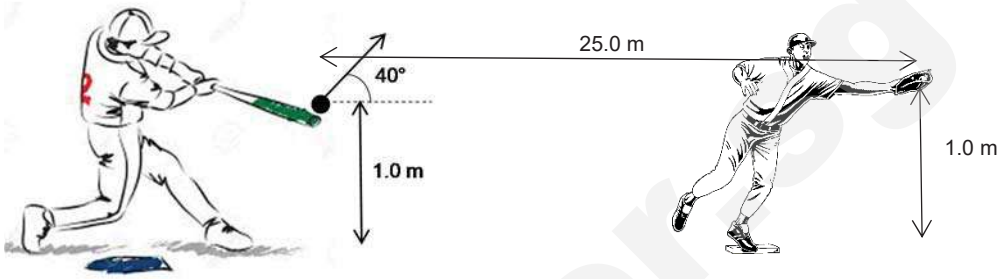

Fig. 2.3

(Not drawn to scale)
Source: clipart panda

Average speed = ... m s^{-1} [3]

(ii) Hence or otherwise, comment if it is likely that the outfielder is able to catch the baseball.

.....

.....[1]

3 A 220 kg satellite is travelling in a circular orbit at a distance of 640 km above the surface of Earth.

The Earth has a radius of 6.37 x 10^6 m and mass 5.98 x 10^{24} kg.

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(a) Determine the speed of the satellite.

speed = ... m s^{-1} [3]

(b) The satellite loses mechanical energy at the average rate of 1.4 x 10^5 J per orbital revolution. The satellite's orbit can be approximated to be a circle of diminishing radius.

(i) Show that the total energy of a satellite is given by $-\frac{GMm}{2r}$, where M is the mass of Earth, m is the mass of the satellite and r is the radius of its orbit.

[2]

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(ii) Hence or otherwise, show that the initial total energy of the satellite is -6.26×10^9 J.

[1]

(iii) Determine the satellite's new orbiting radius at the end of its 1500th revolution.

radius = …….. m [2]

(iv) Hence or otherwise, determine the magnitude of the average retarding force on the satellite.

force = …….. N [2]

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4 (a) (i) Define the *coulomb*.

……

…… [1]

(ii) Explain why a body cannot have a charge of 2.5×10^{-19} C.

……

…… [1]

(b) A battery is connected to a uniform Wire A as shown in Fig. 4.1. The battery is assumed to have negligible internal resistance.

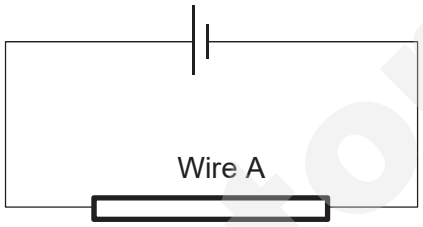

Fig. 4.1

(i) The battery sets up an electric field in the wire, exerting a force on the conducting electrons, causing them to flow across the wire.

Explain why the average kinetic energy of the electron remains unchanged even though its electric potential energy decreases as it flows through the wire.

……

……

……

…… [2]

(ii) Wire B, which has the same material and length as Wire A but twice the cross-sectional area, is connected in series to Wire A.

State and explain if there is any difference between the drift velocity of the electrons in Wire A and Wire B.

……

……

……

……

……[2]

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(iii) Draw the potential graph for the circuit in **(b)(ii)** in Fig. 4.2.

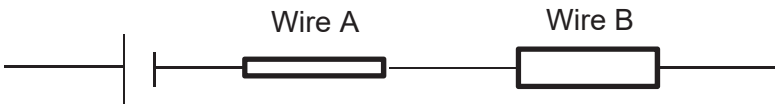



Fig. 4.2

[2]

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5 **(a)** Contactless smart cards, such as EZ-link cards, use electromagnetic induction to power its circuitry without any physical contact with the card reader. Fig. 5.1 below shows a common implementation of such a contactless smart card.

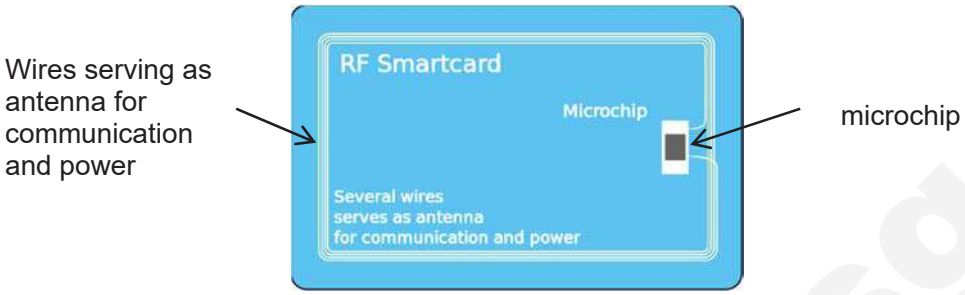

Fig. 5.1

(i) Using Faraday's law of electromagnetic induction, suggest how a smart card reader is able to power the microchip of a contactless smart card without being connected to it by wires.

……

……

……

……

……

……

…… [3]

(ii) A contactless smart card is left on the reader as shown in Fig. 5.2.

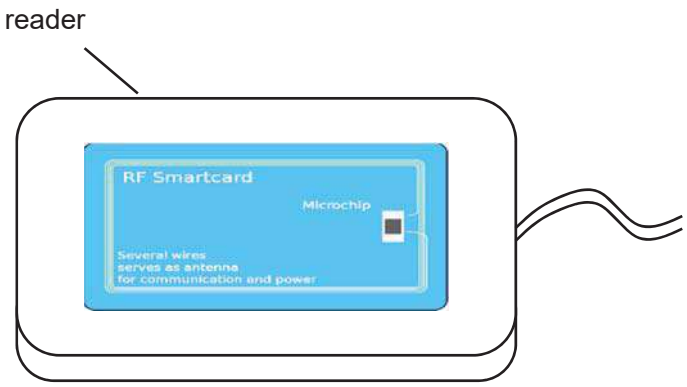

Fig. 5.2

At one instance, the magnetic field generated by the reader is directed out of the surface of the reader, but decreasing in magnitude.

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State and explain, using Lenz's law, the direction of current flowing in the smartcard's antenna.

……

……

……

…… [2]

(b) A transformer steps down the mains voltage of 240 V to 5 V to power a lamp that is rated at 2.0 W, 5 V.

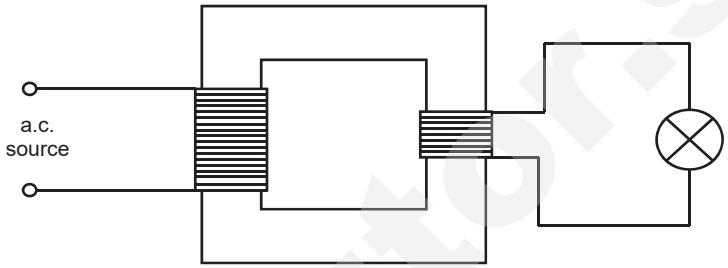

Fig. 5.3

(i) Given that the efficiency of the transformer is 95%, determine the peak current of the ac source.

peak current = …….. mA [3]

(ii) In order to improve the efficiency of power transfer, a student replaces the solid iron core with a laminated iron core.

Explain why this is an effective way to increase the efficiency.

……

……

……

…… [2]

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6 A ball of mass m is suspended from the end of a light spring with spring constant k as shown in Fig. 6.1. At equilibrium, the extension of the spring is x. Air resistance can be neglected.

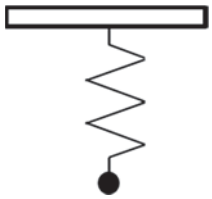

Fig. 6.1

(a) Draw a free body diagram of the forces acting on the ball.

[2]

(b) The ball is given a further downward displacement e and released.

(i) Using Newton's Second Law, show that the relationship between the acceleration of the ball a, and e can be given by $a = -\frac{k}{m}e$.

[2]

(ii) Explain why the motion of the ball is simple harmonic.

……..

……

……

……..

…… [2]

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(iii) Given that m = 0.2 kg, k = 2.0 N m^{-1} and the maximum amplitude is 0.095 m, determine the maximum kinetic energy of the ball.

maximum kinetic energy = ... mJ [2]

(iv) Sketch on Fig. 6.2, graphs of the variations with time of the kinetic energy (label **K**) and the gravitational potential energy (label **U**) for the ball over 2 periods.



Fig. 6.2 [2]

(v) A cardboard is attached to the bottom of the ball.

Sketch on Fig. 6.2, the kinetic energy vs time graph for this scenario and label it as **X**.

[1]

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Section **B**
Answer **one** question from this section

7 **(a)** State the *principle of conservation of momentum*.

.....

.....

..... [2]

(b) Fig. 7.1(a) shows a sphere **A** of mass m_1 and speed u_1, and a sphere **B** of mass m_2 and speed u_2.

Fig. 7.1(b) shows the spheres moving at speeds v_1 and v_2 after a head-on elastic collision.

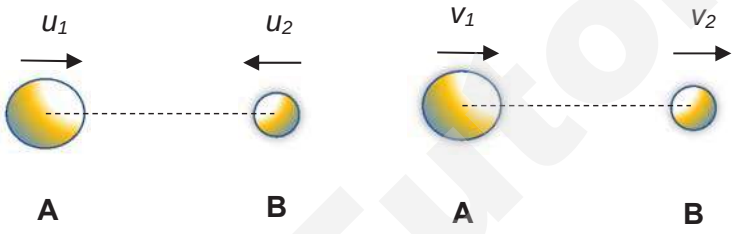

Fig. 7.1(a) **Fig. 7.1(b)**

Given that $m_1 = 3$ kg, $m_2 = 1$ kg, and $u_1 = u_2 = 2$ m s^{-1}.

Complete Table 7.1.

	BEFORE collision		***DURING*** collision and at maximum compression		***AFTER*** collision	
	A	**B**	**A**	**B**	**A**	**B**
momentum / Ns	6	– 2				

Table 7.1

All workings must be shown.

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[5]

(c) Fig. 7.2 shows identical spheres **P**, **Q** and **R**, each of mass *M*, and sphere **S** of mass *m*. Spheres **P**, **Q** and **R** are stationary while sphere **S** is moving at speed *u*. Collisions are taken to be elastic.

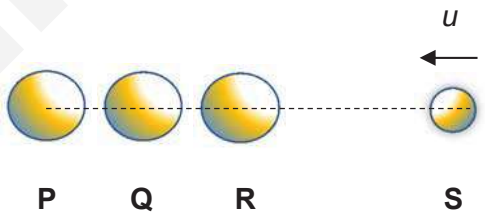

Fig. 7.2

In a head-on elastic collision between 2 spheres, the fraction of the kinetic energy transferred from one sphere to the other is given by

$$\frac{4m_x m_y}{(m_x + m_y)^2}$$

where m_x and m_y are the masses of the 2 spheres.

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Given that $M = 3$ kg, $m = 1$ kg, and $u = 2$ m s^{-1}.

Complete Table 7.2.

	BEFORE any collision has taken place				***AFTER*** *all* collisions are completed			
	P	**Q**	**R**	**S**	**P**	**Q**	**R**	**S**
kinetic energy / J	0	0	0	2				
momentum / Ns	0	0	0	– 2				

Table 7.2

All workings must be shown.

[3]

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(d) (i) 1. State the *Principle of Floatation*.

.....

.....

..... [1]

2. State the *Archimedes Principle*.

.....

.....

.....[1]

(ii) A motorboat powered by an engine which rotates an underwater propeller is shown in Fig. 7.3.

To ensure the propeller blades produce the same constant thrust along each blade, the blades are twisted. The rotating blades have an effective radius r which pushes the water backward with a velocity v relative to the boat. The water can be considered to move as a long column of density ρ, radius r and velocity v.

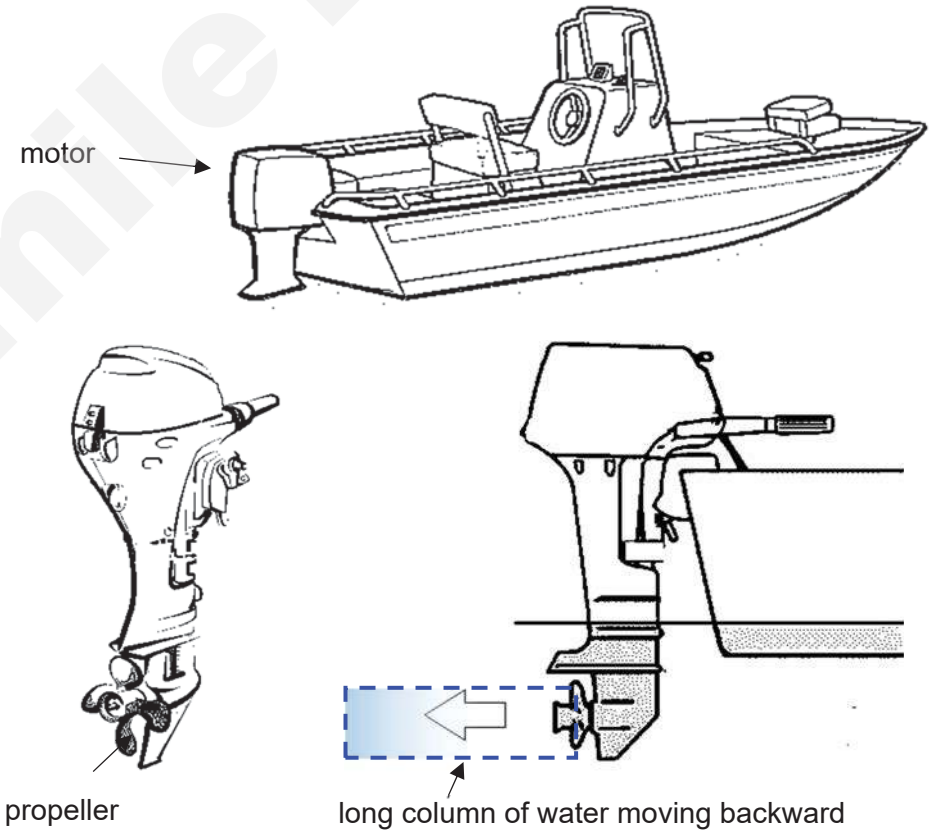

Fig. 7.3

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1. Show that the expression of the force exerted on the water by the propeller blades is

$$F = \pi \rho r^2 v^2$$

[2]

2. Given the following data:

effective radius of propeller blades r	=	25 cm
density of water ρ	=	1000 kg m^{-3}
mass of motorboat and helmsman	=	1400 kg
cruising speed of motorboat	=	12 m s^{-1}
top speed of motorboat	=	18 m s^{-1}
maximum power of motorboat	=	112 kW

Determine the maximum velocity v of the column of water.

v = ... m s^{-1} [3]

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(iii) Fig. 7.4(a) shows a schematic diagram of a motorboat in **(ii)** shaped like a cuboid of base dimensions 6.0 m x 2.0 m.

Fig. 7.4(b) shows the actual shape of the motorboat.

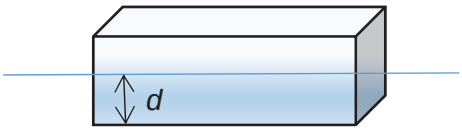

Fig. 7.4(a)



Fig. 7. 4(b)

1. Determine the depth of the waterline *d* when the motorboat is stationary.

d = …….. m [2]

2. When the motorboat is moving at high speed, part of the hull is lifted out of the water as shown in Fig. 7.5.



Fig. 7.5

Explain the reason for the design.

……

……

..... [1]

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For Examiner's Use

8 (a) (i) State the conditions for the formation of observable stationary waves.

……

……

…….. [2]

(ii) A contractor tries to measure the depth of a new well shaft to build a ladder to reach the bottom of the shaft. He uses an audio oscillator with adjustable frequency and applies it across the top of the well. Two successive resonances are heard at 70.6 Hz and 90.8 Hz. The speed of sound is 343 ms^{-1}. Determine the depth of the well.

depth of well = …….. m [3]

(b) (i) State the *Principle of Superposition*.

……

……..

……..

……[2]

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(ii) An engineering student designed an Automated Guided Vehicle (AGV) using interference of radio waves from two coherent emitters 2 m apart emitting radio waves of frequency f that are in phase as shown in Fig. 8.1. The computer on the AGV detects and searches for lines of constructive interference and adjusts the AGV so that it is always align along the middle line of the emitters where one such line of constructive interference is located.

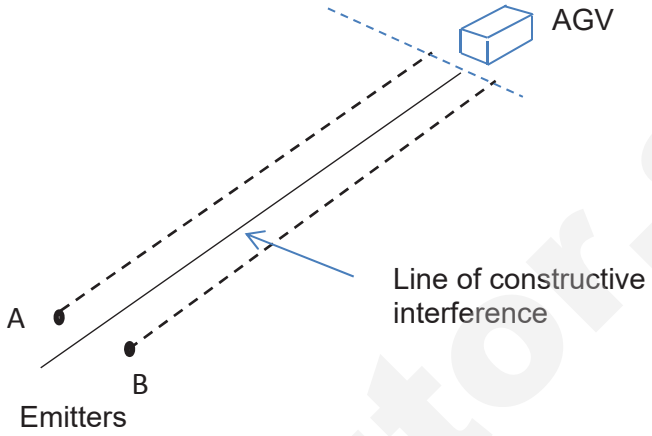

Fig. 8.1

During one such operation, the AGV strays off the centre-line as shown in Fig. 8.2. Fig. 8.3 shows the radio signals X and Y detected by the receiver on the AGV.

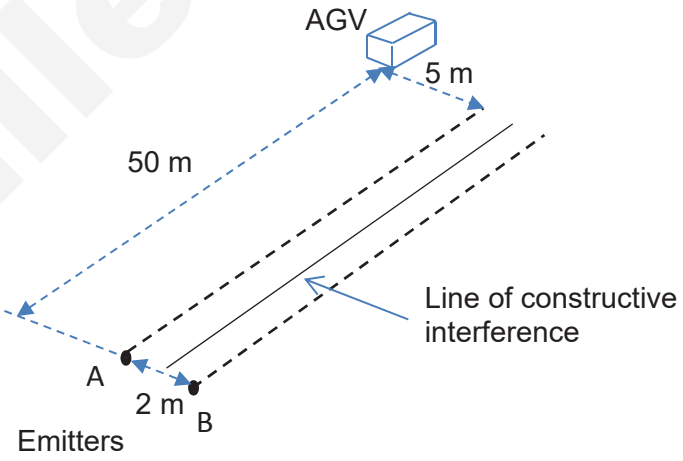

Fig. 8.2

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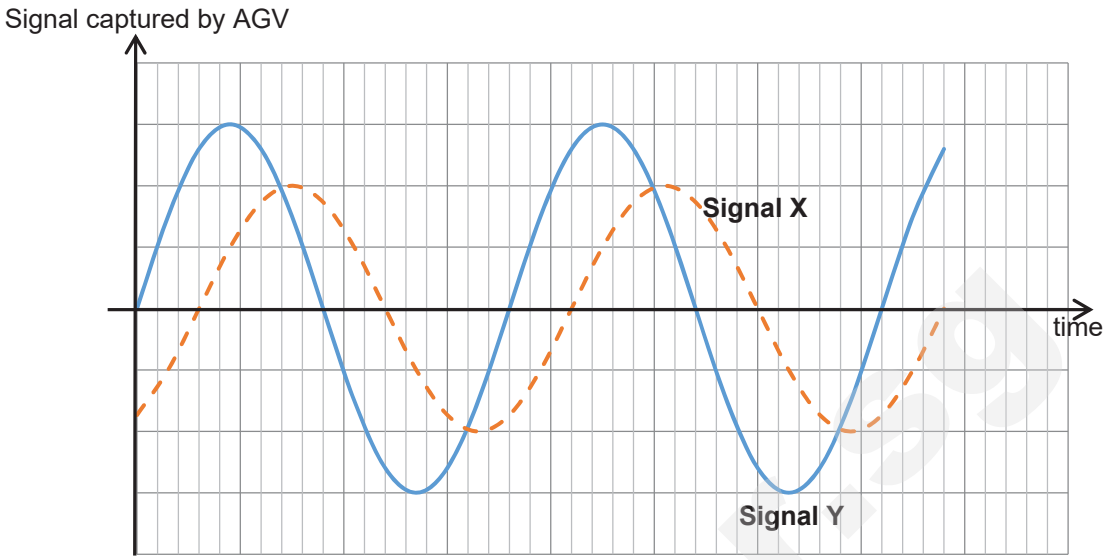

Fig. 8.3

1. State and explain whether the source of signal X is from emitter A or B.

……

……

……[2]

2. State the phase difference between signals X and Y.

phase difference = …….. rad [1]

3. Hence determine the frequency *f* of the radio wave used.

frequency = …….. Hz [4]

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4. Suggest how the AGV can align itself to the centre of the 2 emitters.

.....

.....

.....

.....

.....

.....[2]

(c) Blue light of wavelength 486.5 nm is incident on a diffraction grating. The light is diffracted into a number of beams as shown in Fig. 8.4. The second order bright spots are observed at 0.845 m from the central spot on a screen which is placed at 2.00 m from the grating.

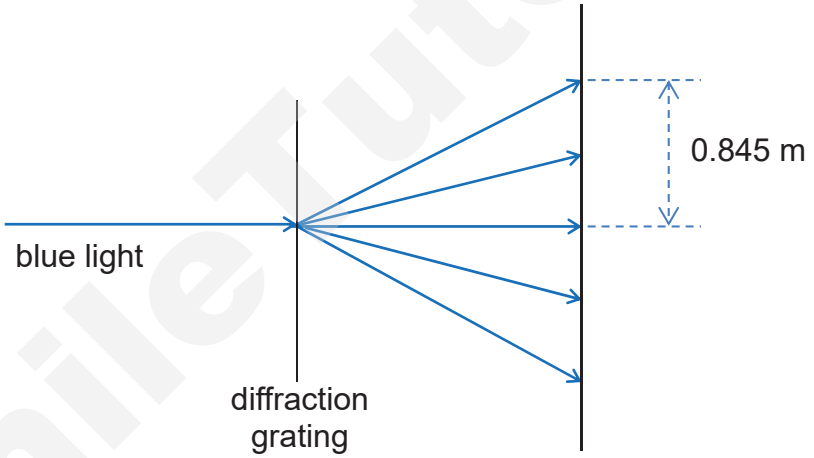

Fig. 8.4

(i) Calculate the number of lines per millimeter on the grating.

number of lines per mm = ... mm^{-1} [2]

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(ii) State and explain an advantage and a disadvantage of obtaining the lines per millimeter of the grating by using the second-order diffracted light rather than the first-order diffracted light.

……

……

……

……

……

…… [2]

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H

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JC2 Physics Preliminary Examination
Higher 2

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CANDIDATE NAME		Form CLASS	
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Paper 4 Practical Test

9749
4 August 2017
2 hour 30 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, Name and Index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the page.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your answers in the spaces provided on the question paper.
The use of approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each Question or part question.

Shift
Laboratory

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Section A	**Marks**
1	/ 20
2	/ 16
3	/ 7
4	/ 12
Total	/ 55

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1. In this experiment, you will time the oscillations of a small mass suspended on V-shaped string at varying angles.

(a) **(i)** Set up the apparatus as shown in Fig. 1.1.

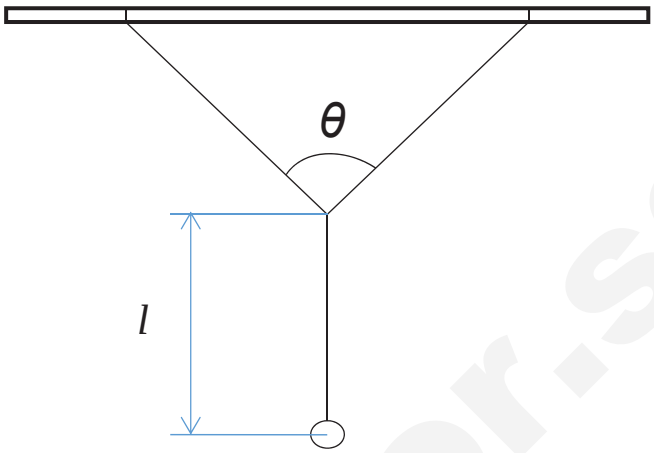

Fig. 1.1

(ii) Measure and record the distance l.

l = …….....

(iii) Measure and record the angle θ.

θ = …….....

(b) Displace the bob through a short distance and release it so that it performs oscillations in a vertical plane at right angles to the rule as shown in Fig. 1.2.

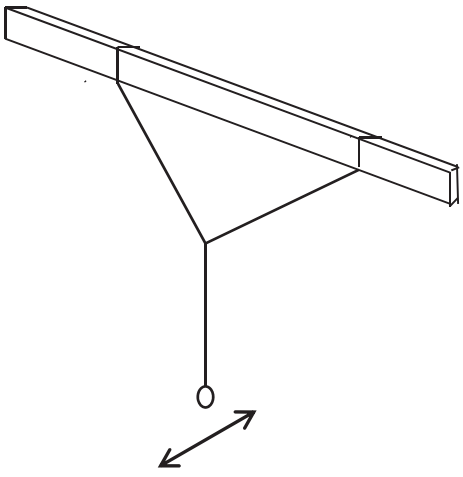

Fig. 1.2

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Make and record measurements to determine the period T of the oscillation.

T = ... [1]

(c) Vary θ in the range $50^0 \leq \theta \leq 150^0$. Repeat to obtain further sets of readings for T.

[6]

(d) Justify if the angle θ has an effect on the period T of the oscillation. Explain your conclusion clearly.

.....

.....

.....

.....[2]

[Turn over

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(e) It is suggested that T and θ are related by the expression

$$T^2 = \frac{4\pi^2 l}{g} cos\frac{\theta}{2} + c$$

where c is a constant and g is the gravitational field strength.

Plot a suitable graph and determine the gradient and the y-intercept of the line.

gradient = …….....

y-intercept = ……..... [3]

(f) Use your values in **(e)** to determine a value for g.

g = ……..... [1]

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[3]

[Turn over

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(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

……

……

……

……[1]

(h) **(i)** State **one** significant source of error in this experiment.

……

……

……

……[1]

(ii) Suggest **an** improvement that could be made to the experiment to address the source of error identified in **(f)(i).** You may suggest the use of other apparatus or a different procedure.

……

……

……

……[1]

(i) In the expression in **(e)**, c is inversely proportional to g. On the same graph grid, sketch a second graph to represent the results if the same experiment is conducted in another location with a higher gravitational field strength.

[1]

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2. In this question, you will investigate if the mass flow rate of salt passing through the hole in a funnel depends on the mass of salt in the funnel.

You are supplied with 2 small containers, Container **A** and **B**, of identical dimensions and holding a total of 90 g of salt. You are also provided with a larger empty container. The mass of salt in Container **A** is m_A and the mass of salt in Container **B** is m_B.

(a) **(i)** Measure and record the depth x of salt in Container **A** using the vernier caliper.

x = ... [1]

(ii) Estimate the percentage uncertainty in your value of x.

percentage uncertainty = ... [1]

(iii) Make further measurements with the vernier caliper to determine the mass m of salt in Container **A** and Container **B**.

m_A = ...

m_B = ... [3]

[Turn over

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(iv) Suggest a modification that can be made to the experiment to improve the reliability of the measurement of x made using the vernier caliper.

……

……

……[1]

(b) Mount the funnel using a retort stand and place the empty container beneath the funnel as shown in Fig. 2.1.

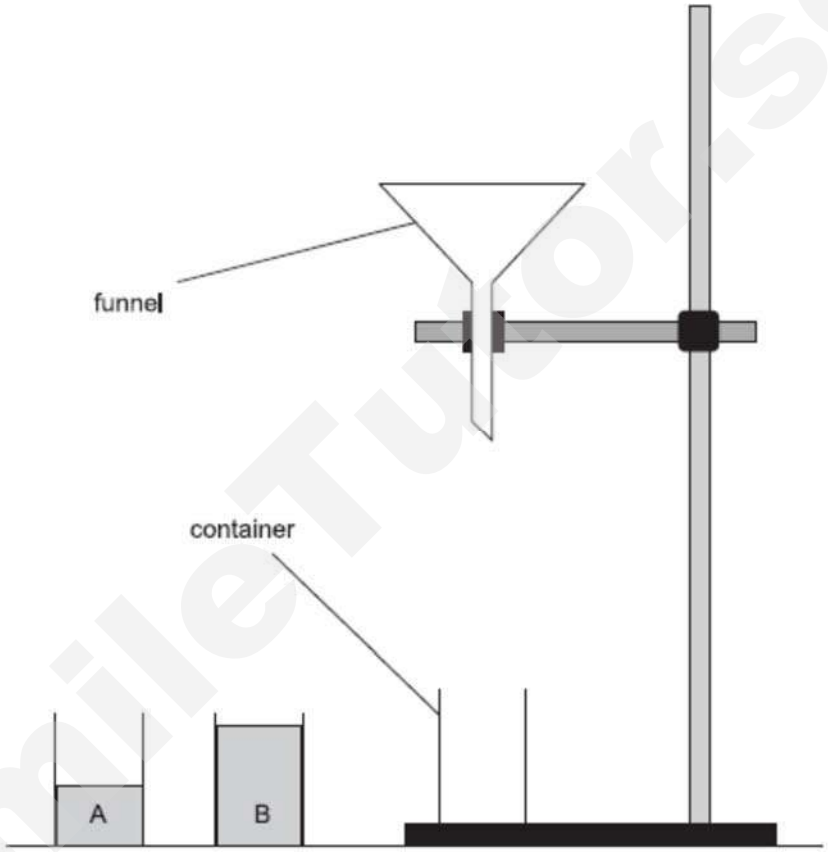

Fig. 2.1

(i) Place your finger over the hole at the bottom of the funnel and pour the salt from Container **A** into the funnel.

Move your finger away and record t_A, the time taken for all the salt to leave the funnel.

t_A = ……..... [1]

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(ii) Estimate the percentage uncertainty in t_A.

Percentage uncertainty in t_A = ... [1]

(c) The mass flow rate of a material can be defined by the rate of flow of the mass per unit time.

Determine the mass flow rate of the salt from Container **A** through the funnel.

Mass flow rate of salt in Container **A** = ... [1]

(d) State and explain which of the 2 measurements, t_A or m_A, has a more significant effect on the uncertainty of mass flow rate.

.....

.....

.....[2]

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(e) It is suggested that an increase in mass of salt in the funnel will increase the mass flow rate of the salt through the funnel.

With the apparatus given, take further measurements to investigate the relationship between the mass of the salt in the funnel and its mass flow rate. Use your results to comment whether you agree with this suggestion.

Present your measurements and calculated results clearly.

……

……

……

……[4]

(f) In practice, hoppers used in food processing industry are used to store and dispense loose material such as grains. The design of the hopper bears resemblance to a funnel.

As the size of grains may vary, suggest one method that can be used to maintain the flow rate during the dispensing of the grains.

……

……

……

……[1]

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3. In this experiment you will investigate the contents of Box **A** and Box **B** which contain resistors.

The contents of the boxes are shown below in Fig. 3.1.

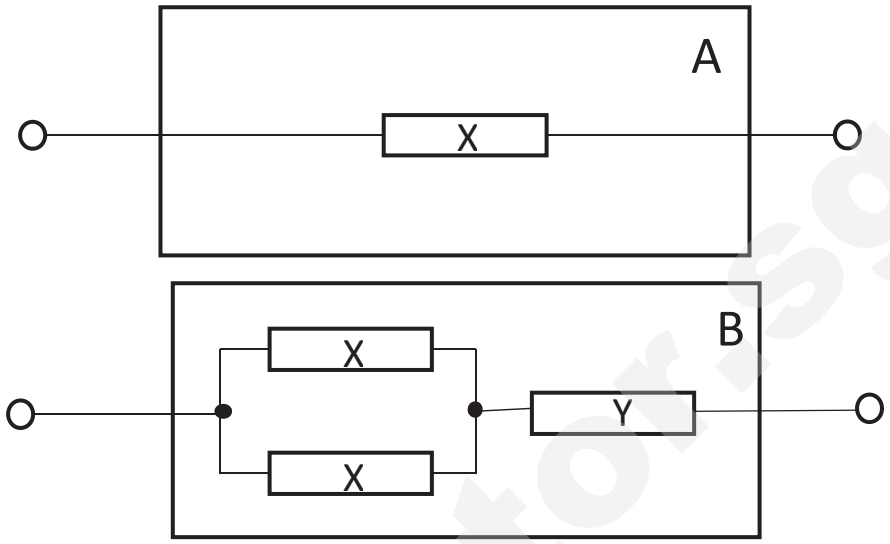

Fig. 3.1

(a) Set up the digital multi-meter as an ammeter to measure current with a range of 200 mA.

Use the 1.5 V dry cell and the digital multi-meter to set up a circuit to estimate the resistance of Resistor **X** and Resistor **Y**.

Draw a circuit diagram of your setup and show your readings and working clearly.

Resistance of Resistor **X** = …….....

Resistance of Resistor **Y** = ……..... [4]

[Turn over

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(b) Set up the digital multi-meter as an ohmmeter by selecting the appropriate range for resistance measurement. Make direct measurement and obtain readings for boxes **A** and **B**. Determine the resistance of Resistor **X** and Resistor **Y**.

Resistance of Resistor **X** = ……..…

Resistance of Resistor **Y** = ……[2]

(c) Justify the differences in the values obtained in **(a)** and **(b).**

……

……

……

……[1]

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4. Static friction can be defined as the frictional force which exist between a stationary object and the surface it is in contact with. The magnitude of static friction that an object experiences can vary over a range of values. It can be affected by factors such as the mass of the object, the magnitude of the external force that is exerted on the object and the texture of the surface that it is in contact with. The maximum static friction can be defined as the magnitude of the force the surface exerts on the stationary object just before the object starts to move.

When an object is placed on a circular disc and the disc starts to spin about its centre, the static friction provides the centripetal force to keep the mass on the same location on the disc. The mass can be observed to start slipping when the angular velocity of the disc exceed a certain value.

A student suggested that the relationship between the angular velocity of the disc, ω, the mass of the object, m, and its distance from the centre of the disc, r, may be written in the form

$$\omega = k\, r^x\, m^y$$

where k, x and y are constants.

You are provided with a motor which has an axle that is attached to the centre of a circular disc. You may also use any of the other equipment usually found in a physics laboratory.

Design an experiment to determine the values of k, x and y.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables
(b) the equipment you would use
(c) the procedure to be followed
(d) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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……

……

……

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JC2 H2 Physics
Preliminary Examinations Paper 1 MS

1	A	16	D
2	D	17	A
3	A	18	C
4	A	19	A
5	D	20	D
6	D	21	B
7	A	22	D
8	D	23	A
9	C	24	A
10	C	25	C
11	D	26	D
12	B	27	B
13	D	28	B
14	A	29	C
15	B	30	C

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Qn	MS
1a) (i)	$T - m_B g = m_B a$ $T - 3g = 3a$
	$10g\sin 30° - T = 10a$ $5g - T = 10a$
	$13a = 2g$ $a = 1.51 ms^{-2}$
(ii)	$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv_f^2$ $\frac{1}{2}(3)(0.5)^2 + 3g(2) = \frac{1}{2}(3)v_f^2$
	$v_f = 6.28 ms^{-1}$
1 b)	Gain in gpe = -Work done by conservative force
	= - F_gD =- (mg(-h))
	= mgh

2(a)(i)	momentum after elastic collision = - mu time between collisions = 2L/u number of collisions per unit time = u/2L
	rate of change of momentum = - mu^2/L average force = mu^2/L
(b)(i)	Gas molecules collide with one another elastically
(ii)	Since KE is conserved, the average speed of the gas molecule incident on the wall remains the same.
	Frequency of collision between each wall and the molecule remains unchanged.
(c)	*pV* = 1/3 *Nm*<c^2>
	NkT = 1/3 *Nm*<c^2>
	(3/2)kT = Ave KE *T* α *Ave KE*

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(d)(i)1.	Area under graph bounded by y-axis
2.	Hence $P_AV_A = P_BV_B$ Difference is 0
(iii)	If expansion takes place very quickly, Q = 0
	There is an decrease in KE of the gas hence mean square speed decreases

3a) (i)	Out of the page
(ii)	Apply an Electric Field with E. Field strength in the upwards direction
(iii)	$qE = Bqv$
	$v = \frac{E}{B}$
(b) (i)	$\frac{1}{2}mv^2 = 10eV$ $\frac{1}{2}(9.11\times10^{-31})v^2 = 10(1.6\times10^{-19})$
	$v = 1.87\times10^6 ms^{-1}$
(ii)	The magnetic force provides the centripetal force
	$Bqv_{vert} = \frac{m_e v_{vert}^{\ 2}}{r}$ $Bq = \frac{m_e v_{vert}}{r} = m_e w$ $\frac{2\pi}{T} = \frac{Bq}{m_e}$ $T = \frac{2\pi m_e}{Bq}$
	Pitch, p = V_{hor}T = (v cos θ)(T)
	$p = \frac{v\cos\theta(2\pi m_e)}{Bq}$
(iii)	$3p = \frac{v\cos\theta(2\pi m_e)}{Bq}\times3$ $= \frac{1.87\times10^6(\cos60°)(2\pi)(9.11\times10^{-31})}{(5\times10^{-4})(1.6\times10^{-19})}\times3$
	$= 0.201m$

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4a)	Electric field strength at a point in the field is defined as the electric force experienced per unit charge
	by a small stationary positive point test charge placed at that point and is in direction of the electric force on a positive test charge at that point

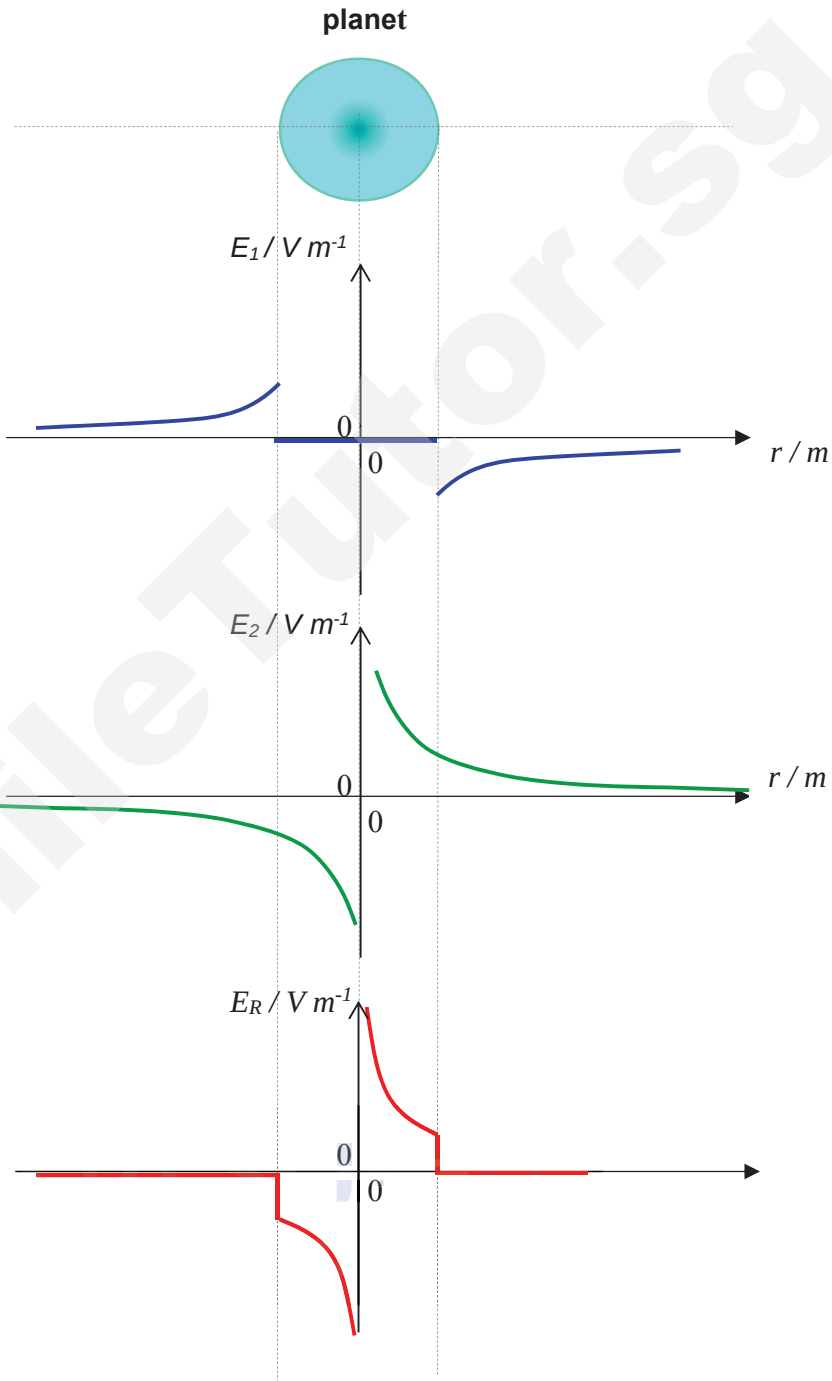

Fig. 4.1(a)

Fig. 4.1(b)

Fig. 4.1(c)

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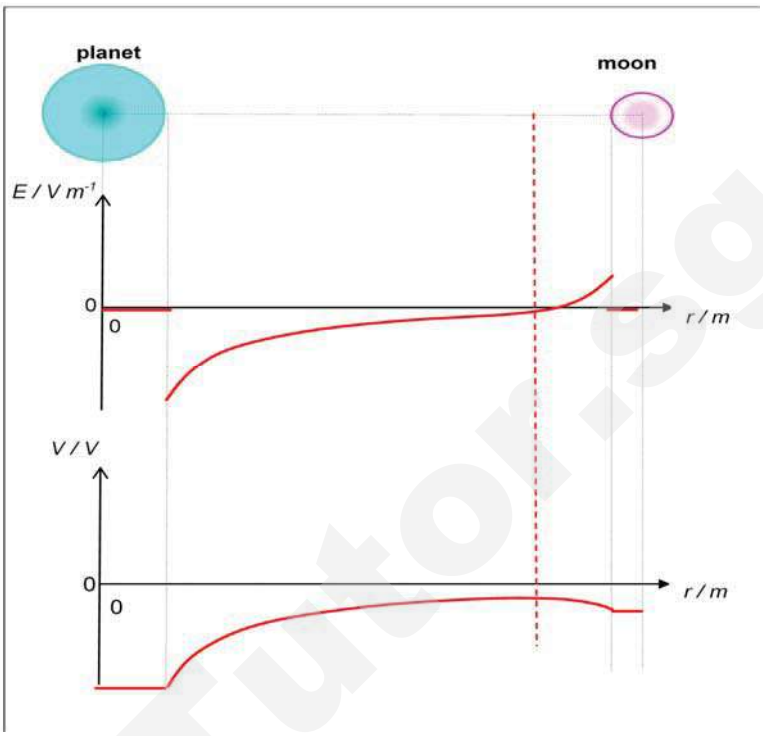
	(b)	Inside mass : both graphs E_1 and E_2 are correct
		Outside mass : both graphs E_1 and E_2 are correct
		E_3 is correct based on graphs E_1 and E_2
	(c)	
		E graph is correct, magnitude of E near earth > magnitude of E near moon
		V graph is correct, magnitude of V near earth > magnitude of V near moon
		$E = 0$ coincides with $\frac{dV}{dr} = 0$
	(d)	$F = qE$ $a_y = \frac{qV}{m_e d} = \frac{(1.6\times10^{-19})(80)}{(9.11\times10^{-31})(4\times10^{-3})}$ $= 3.51\times10^{15}\, ms^{-2}$
		$S_y = u_y t + \frac{1}{2}a_y t^2$ $2\times10^{-3} = \frac{1}{2}(3.51\times10^{15})t^2$ $t = 1.07\times10^{-9}\, s$
		$S_x > 0.05$ $u_x t > 0.05$ $u_x > \frac{0.05}{1.07\times10^{-9}}$ $= 4.673\times10^{7}\, ms^{-1}$
		$u_x = 4.68\times10^{7}\, ms^{-1}$

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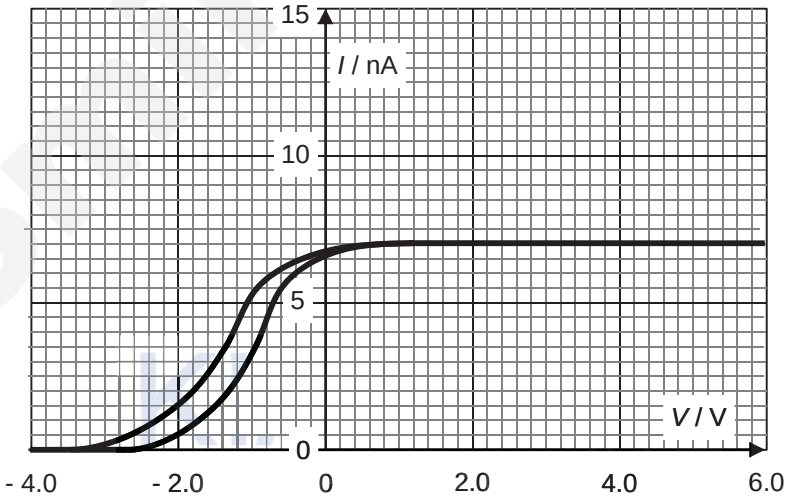
5(a) (i)	dip in intensity at specific wavelengths
	Absorption spectrum
(ii)	Transition is least energetic transition out of all the transitions to n=2, i.e. transition giving rise to 656 nm line.
	$\Delta E_{656nm} = \dfrac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{656\times10^{-9}}$ $= 3.03\times10^{-19}$
	$E_3 = E_2 + \Delta E_{656nm}$ $= -5.44\times10^{-19} + 3.03\times10^{-19}$ $= -2.41\times10^{-19}$ J / -1.51eV
(b) (i)	EM waves will continuously transfer energy to the electrons to overcome the work function.
	Even if lower frequency waves are used, the electrons can accumulate energy over time to gain enough energy to overcome the work function
	Hence no minimum frequency should exist.
(ii)	Stopping potential correctly identified: -2.6V or -2.7V
	$\phi = \dfrac{hc}{\lambda} - eV_s$ $= \dfrac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{\left(184\times10^{-9}\right)} - \left(1.60\times10^{-19}\right)\left(2.6\right)$
	$\phi = 6.65\times10^{-19}$ J(2.6V) $= 6.49\times10^{-19}$ J(2.7V)
(iii)	

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6(a) (i)	$\left(E = BE_{products} - BE_{reactants}\right)$ E = (BE per nucleon of C) x 12 – 3 x (BE per nuceon of He x 4) $E = \left[12 \times \left(7.680\right) - 3 \times \left(4 \times 7.074\right)\right]$	
	7.272 MeV	
(ii)	$P = \frac{E_{total}}{t}$ $= \frac{\text{number of reactions} \times E_{\text{each reaction}}}{t}$ $\frac{\text{number of reactions}}{t} = \frac{P}{E_{\text{each reaction}}} = \frac{2.75 \times 10^{26}}{7.272 \times 10^{6}\left(1.6 \times 10^{-19}\right)}$ $\left(= 2.3635 \times 10^{38}\ \text{s}^{-1}\right)$	
	$\frac{n}{t} = \frac{\text{number of reactions}}{t} \times 3 = \left(2.3635 \times 10^{38}\right)\left(3\right)$	
	$\frac{n}{t} = 7.09 \times 10^{38}$ helium nuclei per second	
(b)	The energy released that is converted into KE of the products is constant	
	The total momentum of the system before and after the reaction is conserved.	
	Since the electron is found to have a range of KE, this means that there must be a third element present in order for COE and COM to be upheld	
(c)	$N_{Rn;initial} = \frac{m}{A_r} \times N_A = \frac{2.0}{220} \times 6.02 \times 10^{23}$ $\left(= 5.4727 \times 10^{21}\right)$	
	$N_{Rn;final} = N_{Rn;initial} e^{-\frac{\ln 2}{t_{1/2}}(t)} = 5.47272 \times 10^{21}\left(e^{-\frac{\ln 2}{56}(60 \times 5)}\right)$ $= 1.3352 \times 10^{20}$	
	$m_{left} = \left(N_{ini} - N_{final}\right) \times \frac{A_{r\,Po}}{N_A} + N_{final} \times \frac{A_{r\,Rn}}{N_A}$ $= \left(5.4727 \times 10^{21} - 1.3352 \times 10^{20}\right)\left(\frac{216}{6.02 \cdot 10^{23}}\right) + \left(1.3352 \times 10^{20}\right)\left(\frac{220}{6.02 \times 10^{23}}\right)$	
	$= 1.96$ g	

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7)a)i)	- Difficult to locate good heat reservoir - Difficult in drilling	
ii)	- Wind condition of the farm - Cost of transmission	
iii)	- unreliable in terms of supply as most are weather dependent - More mature technology which translate into higher efficiency	
b)i)	When the air molecules are incident on the blade, they experience a change in momentum	
	Therefore, by N2L, the blade must have exerted a force on the air molecules	
	By N3L, the air molecules must exert a force of the same magnitude on the blades and thereby turning the blade	
ii)	Mass of air per sec passing thru the turbine= ρV $= 1.23(\pi(50)^2(13.5))$ $= 1.30 \times 10^5$ kg	
	$E = \frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2$ $= \frac{1}{2}(1.30 \times 10^5)(13.5)^2 - \frac{1}{2}(1.30 \times 10^5)(12.8)^2$ $= 1.20 \times 10^6$ W	
	$= 1.20 \times 10^6$ W	
iii)	Energy requirement of town per month = 4100×2000 $= 8.2 \times 10^6 kWh$	
	No. required = $\frac{8.2 \times 10^6}{1.2 \times 10^3 \times 24 \times 30 \times 0.22}$ = 43.14	
	Minimum number required is 44	
c)i)	The slope of the wind lens forces the air inwards at the front of the wind lens and outwards at the exit of the wind lends thereby generating a region of high pressure in front of the wind lens and a region of low pressure behind the wind lens	
	The difference in air pressure in front of and behind the wind turbine exerts an additional force on the air thereby increasing the wind speed.	
ii)	$P_{\text{with lens}}$ = 2.50 $P_{\text{without lens}}$ = 1.00	
	Difference 2.50 – 1.00 = 1.5 kW	
iii)	$P = kv^n$ $\frac{0.20}{1.00} = (\frac{5.50}{9.50})^n$	
	n = 2.94	

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	$P = kv^n$ $1.00 = k(9.50)^{2.94}$ $k = 1.34 \times 10^{-3}$	

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Q		Mark Scheme
1	(a)	unit of D = (units of k)(units of d) units of k = 1
		unit of Q = (units of C)(units of ρ)(units of $\sqrt{g}$)(units of D)$^{3/2}$
		kg s^{-1} = (units of C)(kg m^{-3})($\sqrt{\text{m s}^{-2}}$)(m$^{3/2}$) units of C = m
	(b)	(i) $\rho = \frac{\text{mass}}{\text{volume}}$ $= \frac{0.2125}{\pi(\frac{0.036}{2})^2(0.024)}$ $= 8.70 \times 10^3$ kg m^{-3}
		$\rho = \frac{m}{v}$ $= \frac{m}{\pi(\frac{d}{2})^2 h}$ $\pm\frac{\Delta\rho}{\rho} = \pm(\frac{\Delta m}{m} + 2\frac{\Delta d}{d} + \frac{\Delta h}{h})$
		$= \pm(\frac{0.1}{212.5} + 2(\frac{0.2}{3.6}) + \frac{0.2}{2.4})$ $= \pm 0.195$
		$\pm\Delta\rho = \pm 1.70 \times 10^3$ $\approx \pm 2 \times 10^3$ kg m^{-3} $\therefore \rho \pm \Delta\rho = (9 \pm 2) \times 10^3$ kg m^{-3}
	(b)	(ii) Diameter as the term $2\frac{\Delta d}{d}$ has the largest contribution to the uncertainty of density.

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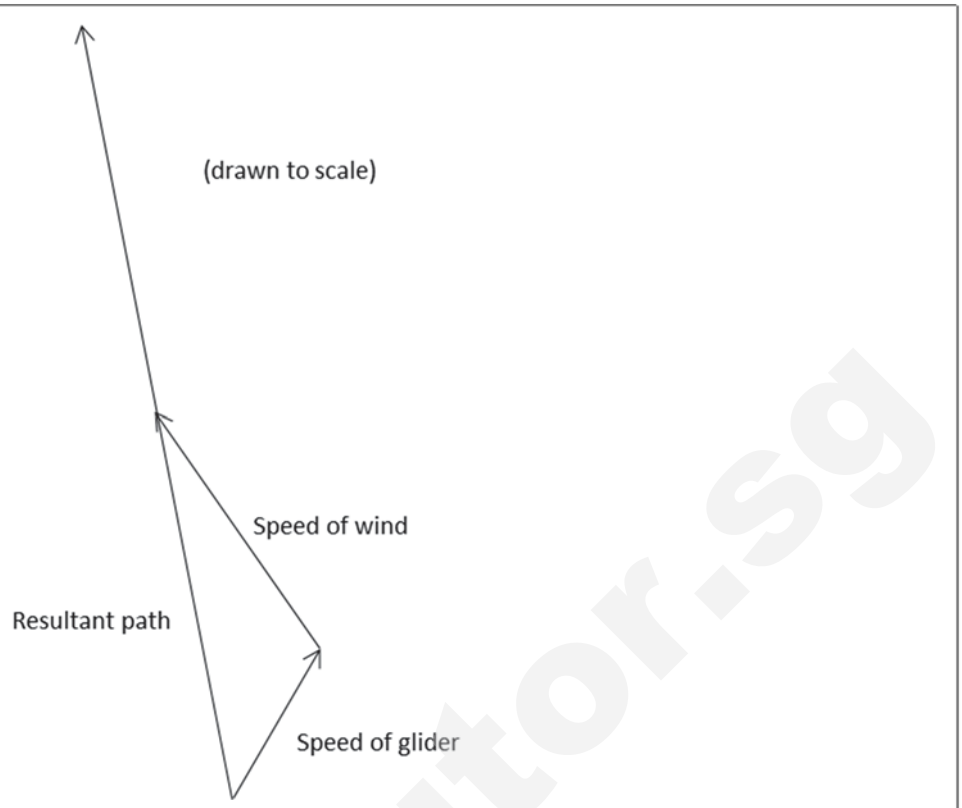
(c)



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2	**(a)**	**(i)**	$v_y^2 = u_y^2 + 2a_y s_y$ $s_y = \frac{(38 sin 40°)}{2(9.81)}$
			$= 30.4m$
			$s_y = 30.4 + 1 = 31.4m$
		(ii)	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mgh$ $v^2 = u^2 + 2gh$ $= (38)^2 + 2(9.81)(1)$
			$v = 38.26 ms^{-1}$
		(iii)	Horizontal distance of second half of curve less than half compared to first half, not symmetrical
			Starting point 1m, max height less than 31.4m
	(b)	**(i)**	$S_y = u_y t + \frac{1}{2}a_y t^2$ $0 = (38 sin 40°)t + \frac{1}{2}(-9.81)t^2$ $t = 4.98s$
			$S_x = u_x t$ $= (38 cos 40°)(4.98)$ $= 145m$
			$Speed = \frac{145 - 25}{4.98}$ $= 24 ms^{-1}$
		(ii)	No, as the fastest 100m sprint time is 10 ms^{-1}

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3	**(a)**		Gravitational force provides the satellite with centripetal force
			$\frac{GMm}{r^2} = \frac{mv^2}{r}$
			$v = \sqrt{\frac{GM}{r}}$
			$v = \sqrt{(\frac{6.67\times10^{-11})(5.98\times10^{24})}{7.01\times10^{6}}}$
			= 7.54 x 10^3 m s^{-1}
	(b)	**(i)**	Gravitational force provides the satellite with centripetal force
			$\frac{GMm}{r^2} = \frac{mv^2}{r}$ $\frac{1}{2}mv^2 = \frac{GMm}{2r}$
			$TE = KE + GPE$ $= \frac{GMm}{2r} - \frac{GMm}{r}$ $= -\frac{GMm}{2r}$
		(ii)	$Total\ Energy = -\frac{GMm}{2r}$
			$Total\ Energy = -\frac{(6.67\times10^{-11})(5.98\times10^{24})(220)}{2(7.01\times10^{6})}$
			= – 6.26 x 10^9 J
		(ii)	Total Energy after 1500 orbits = – 6.26 x 10^9 – (1500)(1.4 x 10^5)
			= – 6.47 x 10^9 J
			$New\ orbit = -\frac{GMm}{2(-6.47\times10^{9})}$
			= 6.78 x 10^6 m
		(iii)	Loss in Total Energy = (Ave retarding force)(ave distance of 1500 orbit)
			Ave retarding force = Loss in TE / average distance
			= 1.4 x 10^5 / 2π [6.895 x 10^6]
			= 3.23 x 10^{-3} N

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4	**(a)**	**(i)**	The coulomb is the amount of charge that passes through a cross sectional area when a current of 1 ampere passes through it for 1 s.
		(ii)	Charge consists of integer multiples of the elementary charge
	(b)	**(i)**	The loss in EPE of the conduction electrons is converted into KE and the collision with neighbouring atoms causes it to lose KE
			Rate of EPE loss and rate of loss of KE is the same, therefore average drift velocity remains the same
		(ii)	Current in both wires are the same
			Electrons in the smaller cross-sectional area wire **A** is higher than the drift velocity compare to wire **B**
		(iii)	The resistances of the wires are high compared to the internal resistance so that current flowing through internal resistance is very small
	(c)	Potential drops across battery, potential increases across resistors and the potential at the beginning and end of graph is the same	
		Increase in potential of thinner wire is twice that of thicker wire.	

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5	**(a)**	**(i)**	The reader produces a varying magnetic field in the area around the card reader.
			The antenna of the card will experience a changing magnetic flux linkage and an emf will be induced
			Since the antenna is a closed circuit, the current will flow into the microchip
		(ii)	The induced magnetic field should be out of the card reader, and
			the induced current is anticlockwise
	(b)	**(i)**	$P = V_{rms} \times I_{rms}$ $I_{rms} = \frac{2}{5} = 0.4A$
			$\frac{V_{rms,pri}}{V_{rms,\sec}} = \frac{I_{rms,\sec}}{I_{rms,pri}}$ $I_{rms,pri} = \frac{5}{240}(0.4)(\frac{1}{0.95}) = 8.77mA$
			$I_{peak,pri} = \sqrt{2}(8.77) = 12.4mA$
		(ii)	With lamination, the paths for eddy current to flow is narrower
			Therefore, eddy current is greatly reduced and hence power loss is reduced

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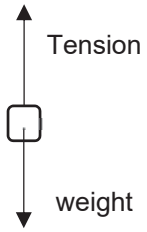
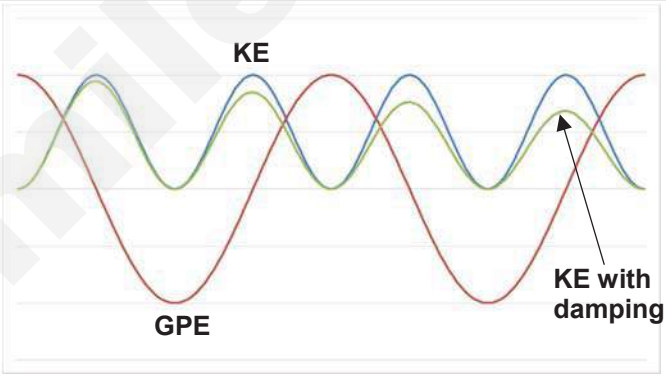
6	(a)		
	(b)	(i)	mg = kx Fnet = ma mg - T = ma
			mg - k(e + x) = ma - ke = ma
			$a = -\frac{k}{m}e$
		(ii)	*a* is directly proportional to *e* as k/m is a constant
			a is always directed towards the equilibrium point as indicated by the negative sign
		(iii)	$KE = \frac{1}{2}mv^2 = \frac{1}{2}m(wx_o)^2 = \frac{1}{2}m((\frac{k}{m})x_o)^2$ $= \frac{1}{2}(0.2)((\frac{2.0}{0.2})(0.095))^2$
			=9.03 mJ
		(iv)	 *
			Sin^2 or cos^2 graph for KE (note freq and 2 cycles)
			Cosine (if ke is sin^2) or sine (if ke is cos^2) graph for gpe (note freq and 2 cycles)
		(v)	Sin^2 or cos^2 graph with decreasing amplitude, to follow graph in (iv)

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7 (a) It states that total momentum is conserved before and after the collision, provided there is no net external force acting on the system.

(b) Before and after collision,

Applying PCOM,

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$
$$(6) - 2 = 3 v_1 + v_2$$
$$4 = 3 v_1 + v_2 \quad \cdots\cdots\cdots\cdots (1)$$

As relative speed of approach = relative speed of separation,

$$u_1 + u_2 = v_2 - v_1$$
$$4 = v_2 - v_1 \quad \cdots\cdots\cdots\cdots (2)$$

$v_1 = 0\ ms^{-1}$ $\quad$ $v_2 = 4\ ms^{-1}$

$m_1 v_1 = 0\ Ns$ $\quad$ $m_2 v_2 = 4\ Ns$

During collision,

At max compression, $v_B = v_A$

$$(m_1 + m_2) v_f = 4$$
$$v_f = 1\ ms^{-1}$$

$m_1 v_1 = 3\ Ns$; $m_2 v_2 = 1\ Ns$

(c)

$$\frac{4 m_x m_y}{(m_x + m_y)^2} = \frac{4(3)(1)}{(4)^2} = 0.75$$

After S collides with R, $KE_S = (1 - 0.75)(2) = 0.5\ J$

$$v_S = \frac{2(0.5)}{1} = 1\ ms^{-1}$$
$$p_S = 1 Ns$$

After R collides with Q, and Q collides with P, $\frac{4 m_x m_y}{(m_x + m_y)^2} = \frac{4(4)(4)}{(4+4)^2} = 1$

Shows KE is fully transferred from R to Q and Q to P

$v_R = v_Q = 0$

$KE_R = KE_Q = 0$

$p_R = p_Q = 0$

$KE_P = 2 - 0.5 = 1.5\ J$

$v_P = \frac{2(1.5)}{3} = 1\ ms^{-1}$

$p_P = -3\ Ns$ as momentum is conserved

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	(d)	**(i)**	**1.**	It states that when a body is wholly or partially immersed in a fluid, it experiences an upthrust that is equal to the weight of the body.
			2.	It states that the upthrust on a body when it is wholly or partially immersed in a fluid is equal to the weight of the displaced fluid.
	(d)	**(ii)**	**1.**	$\vec{F}_W = \frac{d\overrightarrow{mv}}{dt}$
				$= \frac{\rho A l}{t} v$
				$= \frac{\rho(\pi r^2) l}{t} v$
				$= \pi \rho r^2 v^2$
			2.	$F_B = \frac{P}{v}$
				$= \frac{112000}{18} = 6220 N$
				$\vec{F}_W = \pi L^2 \rho v^2$
				$6220 = \pi (0.25)^2 (1000)(v)^2$
				$v = 5.63\ ms^{-1}$
	(d)	**(iii)**	**1.**	*Upthrust on boat* $=$ *weight of boat*
				$\rho V g = mg$
				$(1000)(6.0)(2.0)dg = (1400)g$
				$d = 0.117\ m$
			2.	The length of the wetted surface is reduced, and hence the drag is reduced.

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8	**(a)**	**(i)**	Stationary waves are set up as a result of the superposition of two progressive waves of the same type, having same amplitude and travelling in the opposite directions.	
			The 2 waves must have the same speed and wavelength.	
		(ii)	Show understanding of how the stationary of one open and one close if formed via 2 diagrams	
			$\lambda_1 (\frac{n}{2}+\frac{1}{4}) = D$ $\lambda_2 (\frac{n+1}{2}+\frac{1}{4}) = D$ $\frac{343}{70.6}(\frac{n}{2}+\frac{1}{4}) = \frac{343}{90.8}(\frac{n}{2}+\frac{3}{4})$ $n = 3$	
			$D = 8.50\ m$	
	(b)	**(i)**	The principle of superposition states that the net displacement at a given place and time caused by two or more waves which traverse the same space and meet is	
			the vector sum of the displacement which have been produced by the individual waves separately at that position and instant of time	
		(ii)	**1.**	The intensity of signal is lower as the signal travels further spreads over a larger surface area as it is further from the AGV,
				The signal is from Emitter B.
			2.	$\frac{\pi}{3}$ *or* 60^0
			3.	Dist. from A to AGV = $\sqrt{7^2+50^2}$ = 50.488 m Dist. from B to AGV = $\sqrt{5^2+50^2}$ = 50.249m
				Path Difference = $\frac{\lambda}{6}$ = 50.488 – 50.249 = 0.238m λ = 1.429 m
				$f = \frac{3\times10^8}{2.124}$
				= 2.10 x 10^8 Hz (2 to 3 sf)
			4.	Since the two radio waves are in phase, along the middle line is the line of constructive interference with maximum amplitude,
				the computer should search for the line of constructive interference with the maximum amplitude and align itself to the line.

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	(c)	**(i)**	$\mathrm{d}\sin\theta = \mathrm{n}\lambda$ $d\left(\frac{0.845}{\sqrt{0.845^2+2.00^2}}\right) = 2\left(486.5\times10^{-9}\right)$ $d = 2.5\times10^{-6}$
			No. of lines per m = $\frac{1}{d} = \frac{1}{2.5\times10^{-6}}$ = 4.00 x 10^5 lines/m = 400 lines/mm
			The larger angle of diffraction can be measured experimentally with a lower percentage error with a measuring instrument of a certain precision.
			As it has lower intensity, it is more difficult to determine the centre of the bright fringe.

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Mark Scheme - Determination of Gravitational Field Strength (Question 1)

Section	Skills Assessed	Description	Checklist
MMO Collection	Making measurements	l and angle θ correctly measured with units to the right precision. T correctly measured with units with evidence of repeat readings for value of T with $nT > 20$ s.	1
MMO Collection	Set up apparatus correctly and follow instructions given in the form of written instructions or diagrams	Collected at least 6 or more sets of data (θ, t) w/o assistance/ intervention.	2[6][c]
PDO Table	Layout: Column headings (raw & calculated quantities)	Each column heading must contain an appropriate quantity and unit. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit.	1[6][c]
PDO Table	Table of results: Raw data	Consistency of no. of decimal places for raw readings, based on precision of measurement technique used. For each value of t, $nT > 20$ s.	1[6][c]
PDO Collection	Table of results: Calculated quantities	For each calculated value, the no. of sf should reflect the no. of sf in the raw readings from which it is calculated. All values must be given to an appropriate no. of sf for this mark to be awarded.	1[6][c]
ACE Analysis	Table of results: Calculated quantities	Correct values in calculated quantities. All values should be correct for this mark.	1[6][c]
ACE Analysis	Analysing trend, accuracy and uncertainty	Correct answer - Calculation of difference between max and min T - difference between max and min > uncert	2
ACE Analysis	Linearising Equation	Linearising equation and deriving expressions equating unknowns to gradient & y-intercept of graph.	1[3][e]
PDO Graph	Graph: Layout	Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Axes must be labelled with the quantity (plus relevant unit indicated) which is being plotted.	1[3][grp]
PDO Graph	Graph: Plotting of points	All observations must be plotted. Work to an accuracy of half a small square.	1[3][grp]
PDO Graph	Graph: Trend of graph	Line of best fit drawn. There must be a fair scatter of points on either side of the line.	1[3][grp]
ACE Analysis	Interpretation of Graph	Gradient – the hypotenuse of the Δ sufficiently large (ie greater than half the length of the drawn line). Read-offs must be accurate to half a small sq. Check for $\Delta y/\Delta x$. Value of gradient provided with appropriate units	1[3][e]
ACE Analysis	Interpretation of Graph	Vertical intercept must be read off to nearest half a small sq or determined from $y = mx + c$ using a point on the line. Value of vertical intercept provided with appropriate units.	1[3][e]
ACE Conclusion	Interpretation of Graph	Value of g determined correctly with appropriate units with methods clearly shown.	1
MMO Observation	Identifying of Anomaly	Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise comment on absence of anomalous data.	1
ACE Evaluation	Sources of Errors	Stated and discussed how an error affected the results.	1
ACE Evaluation	Improvements	Stated and discussed how an improvement addressed the error/limitation given above.	1
ACE Evaluation	Interpretation of Graph	Correct graph drawn. - Gradient is less steep with lower vertical intercept	1

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Possible errors

- difficulty in measuring the angle as moving the protractor near string will likely touch the setup and cause it to oscillate, affecting the accuracy of the angle
- difficulty in determining the exact start and end time of the oscillation as the oscillation is too fast

Possible improvements

- clamp the protractor on a retort stand and move it close to the setup close to measure the angle
- take a measure of the setup and measure the angle using the picture
- use a video to record the oscillation and determine the timing using the playback function

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Practical Preliminary Examination (Question 2)

(a)	**(i)**	Measurement of depth x of salt in container A to the appropriate precision with repeat readings	1
	(ii)	Correct method of calculation to get percentage uncertainty rounded to the correct significant figure.	1
	(iii)	Measurement of depth of salt (y) in container B to the appropriate precision with repeat readings	1
		Correct calculation of m_A, $m_A = \frac{x}{x+y}(90)$ g	1
		Correct calculation of m_B by subtraction.	1
	(iv)	Use a narrower and taller containers A and B	1
(b)	**(i)**	Measurement of t_A and recorded with the appropriate precision with repeat readings	1
	(ii)	Absolute uncertainty in t_A in the range 0.2 – 0.4 s. Correct method of calculation to get percentage uncertainty rounded to the correct significant figure.	1
(c)		Mass flow rate calculated correctly with unit	1
(d)		Derived of $\pm\frac{\Delta f}{f} = \pm(\frac{\Delta m}{m} + \frac{\Delta t}{t})$	1
		Correct answer based on the fractional uncertainty	1
(e)		Measurement of t_B and recorded with the appropriate precision with repeat readings.	1
		Second mass flow rate calculated correctly and a correct unit	1
		Correct calculation of the difference in the first and second mass flow rate	1
		Sensible comment relating to the calculated mass flow rates, testing against a criterion specified by the candidate.	1
(f)		ANY ONE 1. Adjust the vibration of the hopper 2. Adjustable size of the opening 3. Stirring the mixture at adjustable rate	1
		Total	15

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Practical Preliminary Examination (Marking Guide to Question 3)

(a)	Correct circuit diagram. Dry cell, multi-meter and A (or B) in series.	1
	Correct calculation of the value of resistane X.	1
	Correct calculation to obtain resistance of components in B	1
	Correct calculation of value of resistance Y.	1
(b)	Correct value of resistance X	1
	Correct value of resistance Y	1
(c)	Internal resistance of the dry cell has not been accounted for.	1
(d)	Use another multimeter and switch the multimeter to measure voltage and connect it across (or parallel to) the boxes A (or B). Calculate the resistance by using R = $\frac{V}{I}$	1
	Total	8

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Diagram		
- must include DC circuit to power the motor - r must be labelled on the disc	1	Max 1
Basic Procedure		
Vary the angular velocity of the disc when the mass slip off. Obtain the time and number of revolution. Determine the angular velocity	1	Max 2
Vary the weight of the mass or vary the distance between the centre of disc to the centre of mass	1	
Measurements		
Count the number of revolutions made and measures the timing using a stopwatch.	1	Max 2
Weigh the mass of the weights using a weighing scale or measure the distance between the centre of the mass using a ruler/vernier calipers	1	
Controlled variable		
Distance when varying mass and mass when varying distance	1	Max 2
Same disc and identical masses has to be used, to ensure constant coefficient of friction	1	
Analysis		
$\omega = kr^x m^y$ $\ln \omega = \ln(kr^x) + y \ln(m)$ when varying mass, where y is the gradient and $\ln(kr^x)$ is the vertical intercept **OR** $\omega = kr^x m^y$ $\ln \omega = \ln(km^y) + x \ln(r)$ when varying distance, where x is the gradient and $\ln(km^y)$ is the vertical intercept	1	Max 2
- Linearise the other variable that was not mentioned earlier	1	
Additional Details		
Ensure that the distance is from the centre of disc to centre of the mass to ensure a more accurate reading of r	1	Max 3 out of which max 1 for safety
Mention way to improve accuracy in recording the timing of time, eg via the use of a light gate with datalogger, etc	1	

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Ensure the timing for the revolutions is long enough to minimize the random error when taking the timing	1	
Ensure the disc is parallel to the horizontal after loading of the mass by ensuring the height at both ends of the disc is the same	1	
Safety		
Wear safety google to prevent mass from hitting the eyes	1	
Place shielding around the setup to prevent the mass to hitting people after slipping from the disc	1	

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9749/01

Paper 1 Multiple Choice

25 September 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

DO **NOT** WRITE IN ANY BARCODES.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages and **0** blank page.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	$T/^{o}$C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux denxity due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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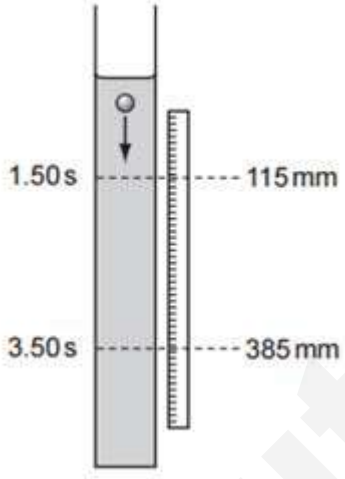
1 A car is travelling along the Pan-Island Expressway under smooth traffic conditions. What is the order of magnitude of its kinetic energy, in joules?

A 10^3 **B** 10^5 **C** 10^7 **D** 10^9

2 The diagram shows an experiment to measure the speed of a small ball falling at constant speed through a clear liquid in a glass tube.



There are two marks on the tube. The top mark is positioned at 115 ± 1 mm on the adjacent rule and the lower mark at 385 ± 1 mm. The ball passes the top mark at 1.50 ± 0.02 s and passes the lower mark at 3.50 ± 0.02 s.

The constant speed of the ball is calculated to be 135 mm s^{-1}.
What is the fractional uncertainty in the value of this speed?

A 0.014 **B** 0.027 **C** 1.9 **D** 3.7

3 An aeroplane travels at an average speed of 600 km h^{-1} on an outward flight and at 800 km h^{-1} on the return flight over the same distance.

What is the average speed of the whole flight?

A 111 m s^{-1} **B** 167 m s^{-1} **C** 686 km h^{-1} **D** 700 km h^{-1}

4 What is the angle of projection for a bullet fired over a horizontal plane, when the horizontal range is four times the maximum height?

A 15° **B** 30° **C** 45° **D** 75°

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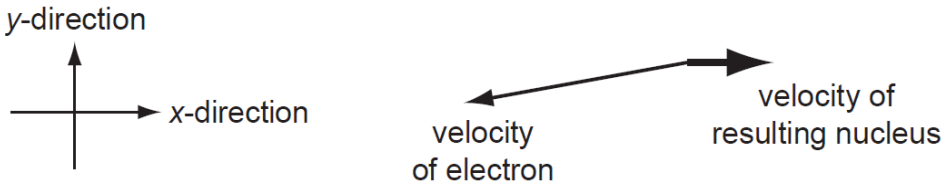
5 A stationary nucleus undergoes beta-decay. The diagram shows the velocities of the resulting nucleus and the emitted electron.



How does this diagram support the idea that a third, unseen particle is also emitted?

A If there were only two particles involved, their velocities should be equal and opposite.

B It is clear that linear momentum is not conserved in the x-direction.

C The third particle must carry away the extra energy.

D The original nucleus had no y-component of linear momentum.

6 A transport system, used to move luggage from the airport terminal to the aircraft, consists of a powered vehicle connected to four baggage carts by a series of connecting bars.



The mass of the powered vehicle is 200 kg and each of the baggage carts has a mass of 400 kg. The system starts with an acceleration of 2.0 m s^{-2}.

What is the tension *T* in the connecting bar between baggage carts 1 and 2?
(Ignore any friction forces on the carts.)

A 800 N **B** 12000 N **C** 2400 N **D** 3600 N

7 A soccer ball approaches a player at v = 12 m s^{-1}. At what velocity u should the player's foot move in order to stop the ball upon contact? Assume that the mass of the foot is much greater than that of the ball and that the collision is elastic.

A u = 12 m s^{-1} in the direction opposite to the original velocity of the ball.

B u = 6 m s^{-1} in the direction opposite to the original velocity of the ball.

C u = 6 m s^{-1} in the same direction as the original velocity of the ball.

D u = 0 m s^{-1}, he should hold his foot very still.

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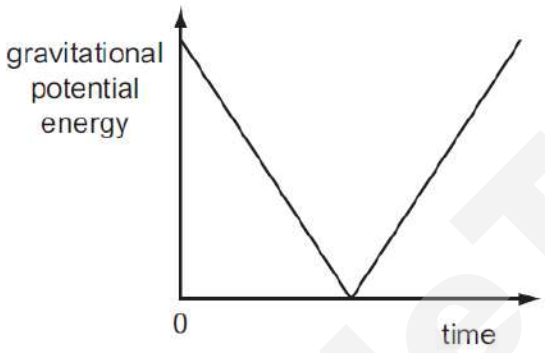
8 A ball is released from rest. It falls vertically, hits the ground and bounces back up. Energy losses are negligible.



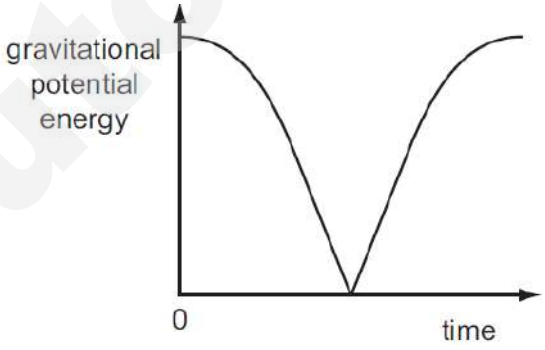


Which graph shows how the gravitational potential energy of the ball changes during the bounce?

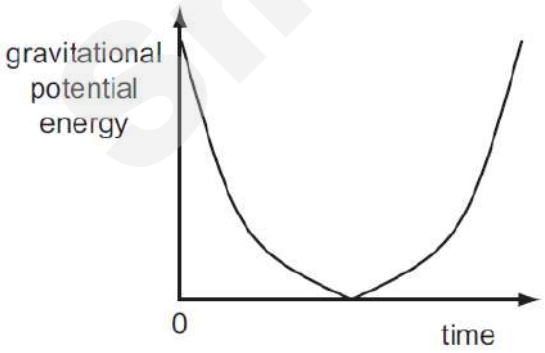
A



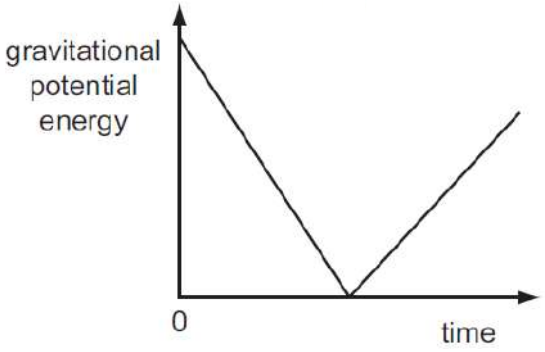
B



C



D



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9 A mass m_1 is attached to one end of an elastic string of unstretched length L. When the mass is rotating with a linear speed of v on a smooth horizontal table in a horizontal circle, an extension e is obtained.

Which of the following shows the correct expression for mass m_2, if it is rotated with the same linear speed v but rotates at twice the radius as that produced by mass m_1?

A $m_2 = \dfrac{2m_1(L+e)}{e}$ **B** $m_2 = \dfrac{2m_1(2L+e)}{e}$

C $m_2 = \dfrac{2m_1(2L+2e)}{e}$ **D** $m_2 = \dfrac{2m_1(L+2e)}{e}$

10 A rocket is travelling away from Earth at a speed of 11 km s^{-1} in a direction at 60° to the Earth's surface at a point where the gravitational field strength is 9.3 N kg^{-1}.

If the mass of the rocket at this moment is 4.0 x 10^6 kg, at what rate is the rocket gaining gravitational potential energy?

A 4.2 x 10^8 W
B 3.6 x 10^{10} W
C 2.1 x 10^{11} W
D 3.5 x 10^{11} W

11 Object X has a mass of 10 kg and object Y has a mass of 60 kg. The gravitational field strength on the Moon is 1.6 N kg^{-1}.

Which statement about objects X and Y is correct?

A The inertia of X on the Earth is greater than its inertia on the Moon.
B The weights of X and Y do not change when they are taken from the Earth to the Moon.
C X experiences the same gravitational field strength as Y on the Moon.
D X has about the same weight on the Moon as Y has on the Earth.

12 The density of argon at a pressure of 1.00 x 10^5 Pa is 1.60 kg m^{-3}. What is the root mean square speed of argon molecules at this temperature?

A 216 m s^{-1} **B** 250 m s^{-1} **C** 306 m s^{-1} **D** 433 m s^{-1}

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13 Before the invention of the modern refrigerator, ice was manufactured industrially and delivered to households. One method used the evaporation of ammonia. Energy was required to make the ammonia evaporate and 75% of this energy came from liquid water at 0 °C, turning the water into ice. In six hours 8.0×10^4 kg of ice was produced.

At what rate did the ammonia need to be evaporated?

The specific latent heat of fusion of water is 330 kJ kg^{-1}.
The specific latent heat of vaporisation of ammonia is 1370 kJ kg^{-1}.

A 0.67 kg s^{-1} **B** 1.2 kg s^{-1} **C** 12 kg s^{-1} **D** 20 kg s^{-1}

14 A particle is oscillating in simple harmonic motion. When the particle is mid-way between the equilibrium position and amplitude position, what is ratio of its kinetic energy to its potential energy?

A 1:3
B 1:1
C 3:1
D 1:7

15 A pendulum clock is being operated in a lift. What will happen to the pendulum when the lift cable snaps?

A The pendulum bob will hit the ceiling of the lift.
B Oscillations will continue but the period will increase.
C Oscillations will continue but the period will decrease.
D Oscillations will stop.

16 Two sources of radio waves are at a distance of 1.0×10^{15} m from Earth. The sources are separated by 1.0×10^{12} m and emit radio waves of wavelength 0.030 m.

What is the estimate for the diameter of a dish of a radio telescope on Earth that will just resolve the two sources?

A 3.0×10^{-5} m
B 3.0×10^{-2} m
C 3.0 m
D 30 m

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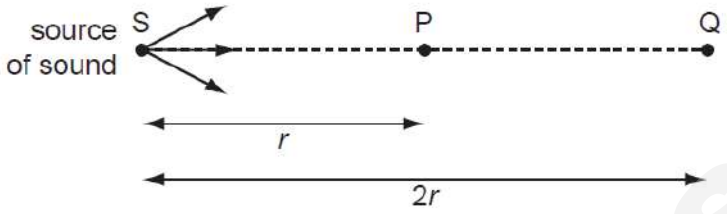
17 The intensity I of a sound at a point P is inversely proportional to the square of the distance x of P from the source of the sound. That is

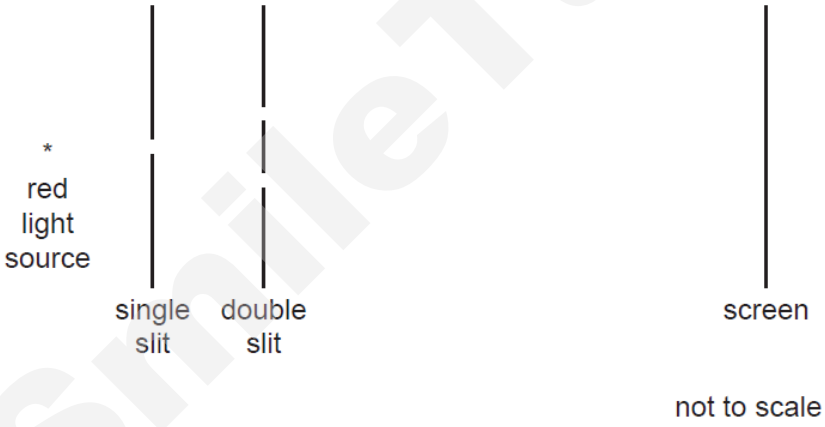
$$I \propto \frac{1}{x^2}.$$



Air molecules at P, a distance r from S, oscillate with amplitude 8.0 μm.
Point Q is situated a distance $2r$ from S.
What is the amplitude of oscillation of air molecules at Q?

A 1.4 μm **B** 2.0 μm **C** 2.8 μm **D** 4.0 μm

18 A double-slit interference experiment is set up as shown.



Fringes are formed on the screen. The distance between successive bright fringes is found to be 4 mm.

Two changes are then made to the experimental arrangement. The double slit is replaced by another double slit which has half the spacing. The screen is moved so that its distance from the double slit is twice as great.

What is now the distance between successive bright fringes?

A 1 mm **B** 4 mm **C** 8 mm **D** 16 mm

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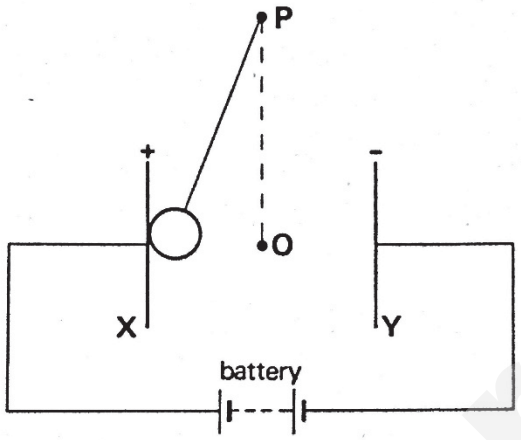
19 Two parallel plates **X** and **Y** are mounted vertically and given equal and opposite charges. A light uncharged conducting sphere is suspended by an insulating thread from point **P** vertically above the mid-point **O** of the line joining the centre of the plates.



If the sphere is initially placed in contact with **X** as shown in the diagram, which statement best describe its subsequent motion?

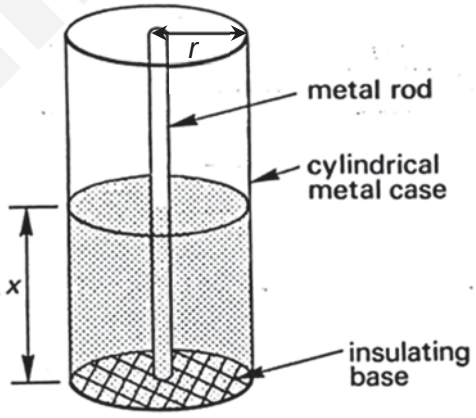
A It remains in contact with plate **X**.

B It moves to plate **Y** and sticks to it.

C It moves back and forth continuously, touching each plate in turn.

D It oscillates as a simple pendulum.

20 A conducting liquid fills a cylindrical metal case to a depth x as shown in the diagram.



The resistance between the case and the metal rod is

A proportional to x.

B proportional to r.

C inversely proportional to x.

D inversely proportional to r^2.

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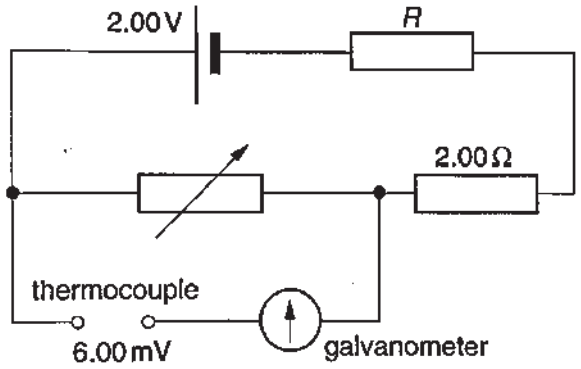
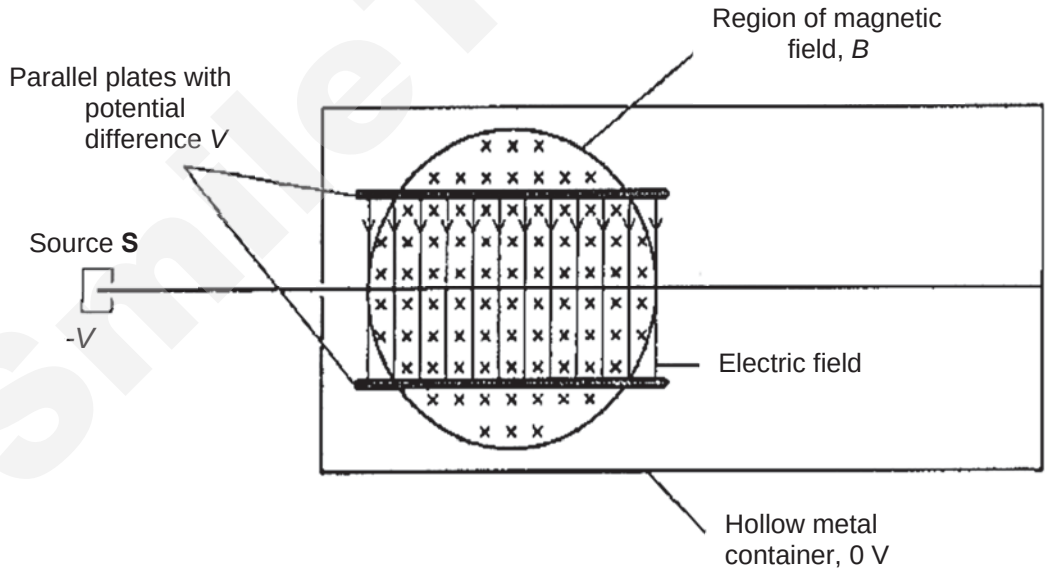
21 The diagram shows a circuit for measuring a small e.m.f. produced by a thermocouple.



There is zero current in the galvanometer when the variable resistor is set at 3.00 Ω.
What is the value of the resistance *R*?

A 195 Ω **B** 495 Ω **C** 995 Ω **D** 1995 Ω

22 A part of a mass spectrometer is shown in the figure below. Negative ions are generated at the source **S**, which is at a potential of $-V$ with respect to the hollow metal container. Inside the container, there are parallel plates separated by distance *d* and a uniform magnetic field *B* is applied to the region between the parallel plates.



If the potential difference between the parallel plates is *V*, what is the charge to mass ratio of the ions that can pass through the fields undeviated?

A $\frac{V}{2B^2d^2}$ **B** $\frac{2V}{B^2d^2}$

C $\frac{2B^2d^2}{V}$ **D** $\frac{B^2d^2}{2V}$

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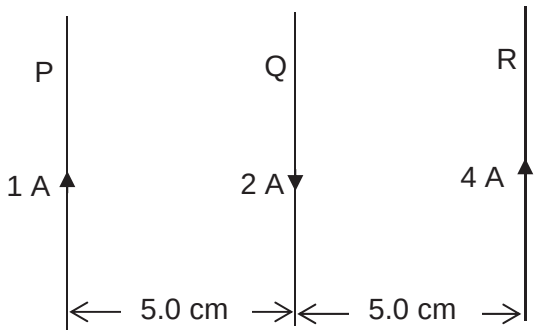
23 Three long, parallel, straight wires P, Q and R are placed in the same plane in a vacuum as shown in the diagram below.



What is the force per unit length acting on wire P?

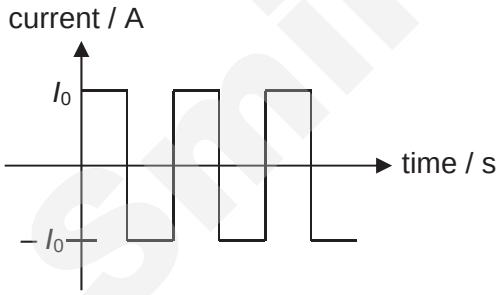
A 0

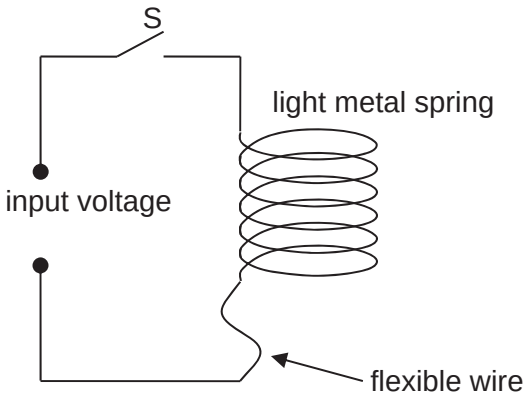
B 8.0×10^{-6} N m^{-1}

C 1.6×10^{-7} N m^{-1}

D 1.6×10^{-5} N m^{-1}

24 The diagram below shows a light metal spring being connected to a circuit. The variation with time of the current produced by the input voltage is shown in the graph below.





What will happen to the spring when switch S is closed?

A The spring will be compressed slightly.

B The spring will be extended slightly.

C The spring will oscillate with the same frequency as the input signal.

D Nothing will happen.

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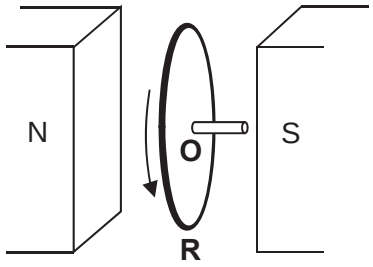
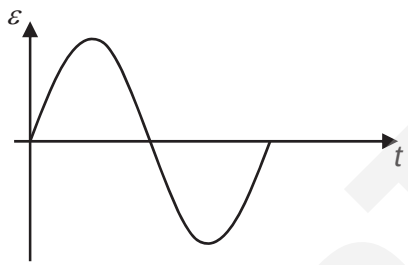
25 The figure below shows a copper disc rotating steadily about its centre **O** in a uniform magnetic field between two bar magnets. The magnetic field is acting perpendicularly to the disc.

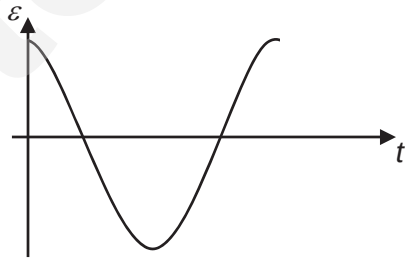


Which of the following graphs correctly shows the variation of the induced e.m.f. ε between the centre **O** and a point **R** on the rim of the disc with time t?

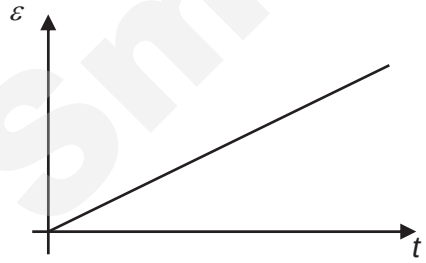
A



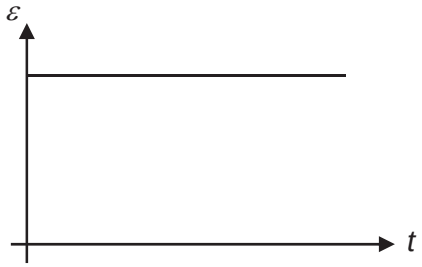
B



C



D



26 Ten 12 V 24 W lamps are connected in parallel to the secondary coil of a step down transformer whose primary coil is connected to the mains supplying 240 V. The lamps are operating normally at the given rating. If the primary current drawn from the mains is 1.1 A, what is the efficiency of the transformer?

A	91 %	**B**	9 %
C	53 %	**D**	86 %

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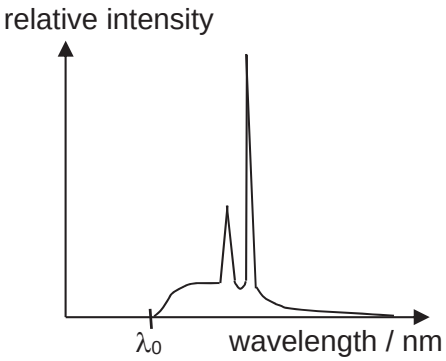
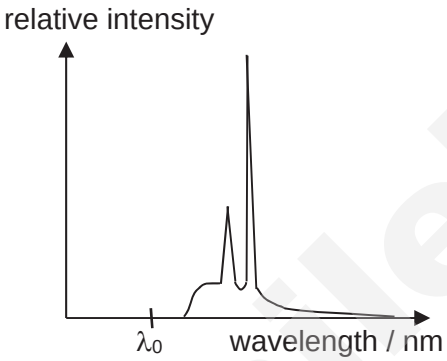
27 An X-ray spectrum is taken from an X-ray tube. The relative intensity of the X-rays is plotted against the wavelength and is shown below.

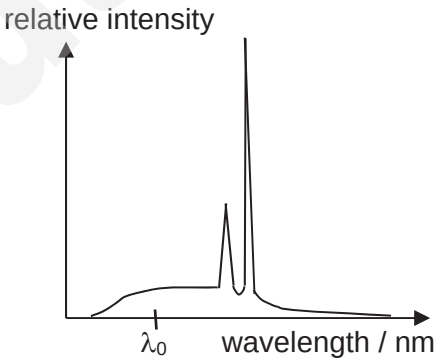


If a higher tube voltage is used, which one of the following graphs shows the new variation of the relative intensity with wavelength?

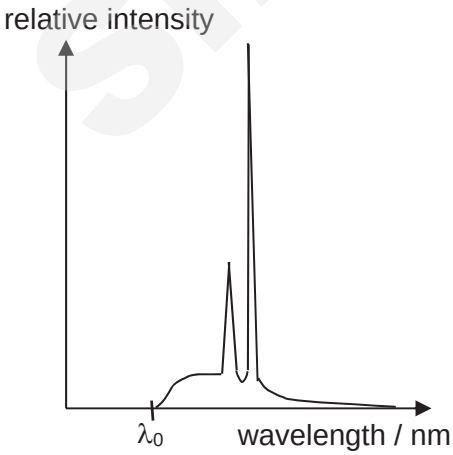
A



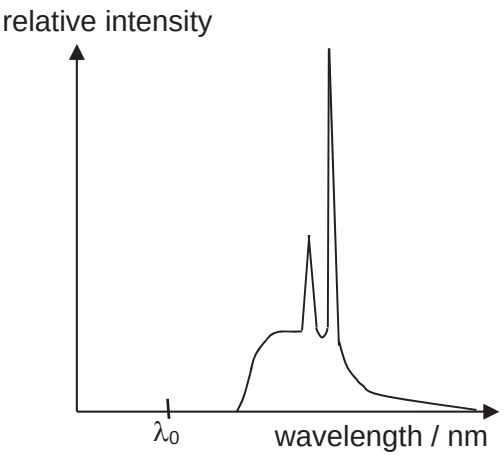
B



C



D



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28 Which one of the following statements about the photon is **incorrect**?

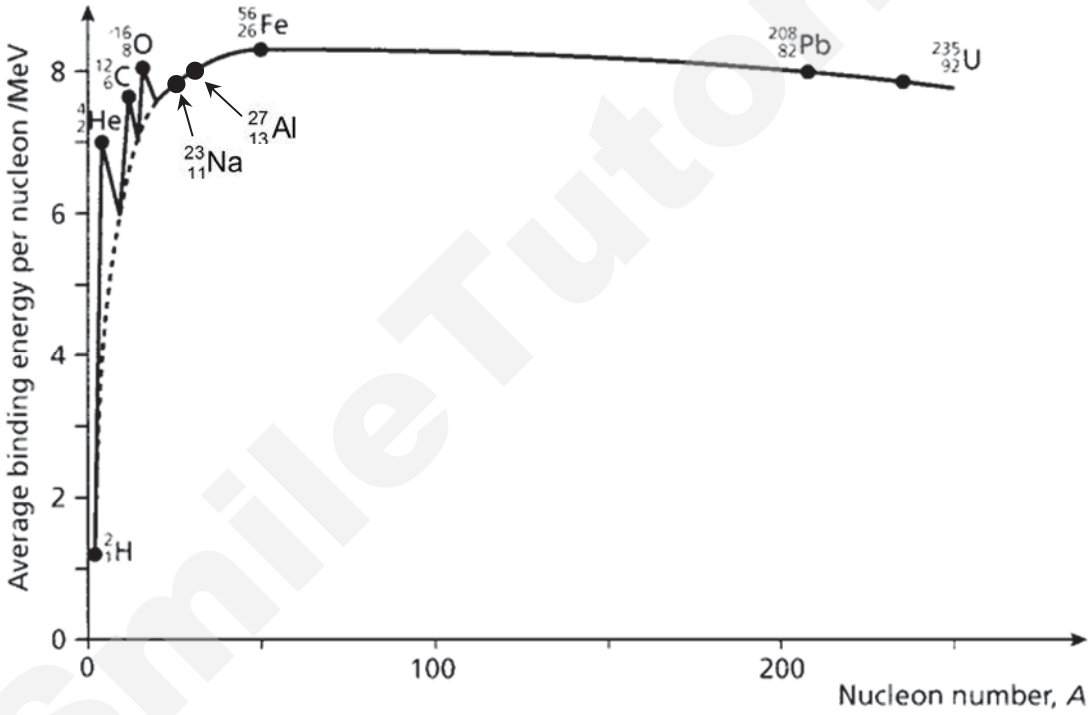
A A photon has no mass.

B A photon has no momentum.

C All photons move with the same speed in free space.

D Photons are emitted when a high energy electron beam is stopped by a piece of molybdenum metal.

29 The diagram shows a graph of the binding energy per nucleon for a number of naturally occurring nuclides plotted against their nucleon number.



Which of the following statements is a correct deduction from the graph?

A Of the nucleus plotted, $^{2}_{1}H$ is the most stable.

B $^{27}_{13}Al$ will not spontaneously emit an alpha particle to become $^{23}_{11}Na$.

C Energy will be released if a nucleus with a nucleon number greater than about 56 undergoes fusion with any other nucleus.

D Energy will be released if a nucleus with a nucleon number less than about 56 undergoes fission as a result of particle bombardment.

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30 A strontium-90 nucleus emits a α– particle and decays to yttrium (Y). The decay has a half-life of 28 years. In a laboratory source of strontium-90, the number of atoms present in January 2016 was 2.36×10^{13}.

What is the number of strontium atoms that will be present in the source in January 2128?

A 7.38×10^{11}

B 1.48×10^{12}

C 3.93×10^{12}

D 5.90×10^{12}

END OF PAPER

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9749/02

Paper 2 Structured Questions

14 September 2017

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	/7
2	/8
3	/7
4	/13
5	/11
6	/8
7	/6
8	/20
Total	/80

This document consists of **21** printed pages and **1** blank page.

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Data

speed of light in free space,	c =	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o =	8.85×10^{-12} F m^{-1}
		$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	$T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux denxity due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 A 20 kg monkey has a firm hold on a light rope that passes over a frictionless pulley and is attached to a 20 kg bunch of bananas, as shown in Fig. 1.1. The monkey looks up, sees the bananas, and starts to climb the rope to get them.

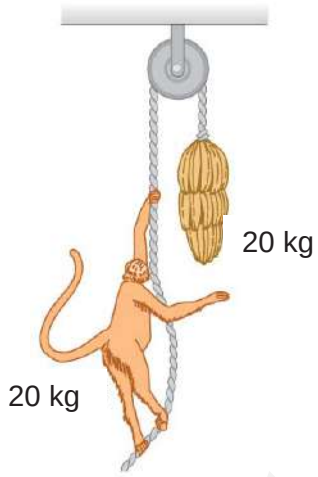

Fig. 1.1

(a) As the monkey climbs,

(i) State the forces acting on the monkey.

……

……[1]

(ii) Hence or otherwise, state and explain whether the bananas move up, down or remain at rest.

……

……

……

……[3]

(iii) State and explain whether the vertical separation between the monkey and the bananas decrease, increase or remain constant.

……

……[1]

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(b) The monkey releases her hold of the rope and both the monkey and bananas fall.

Before reaching the ground, the monkey grabs the rope to stop her fall. State and explain the motion of the bananas while monkey slows down to a complete stop.

.....

.....

.....

.....[2]

2 A block of mass 0.40 kg slides in a straight line with a constant speed of 0.30 m s^{-1} along a horizontal surface, as shown in Fig. 2.1.



Fig. 2.1

The block hits a spring and decelerates. The speed of the block becomes zero when the spring is compressed by 8.0 cm.

(a) Calculate the initial kinetic energy of the block.

kinetic energy = ... J [1]

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(b) The variation of the compression x of the spring with the force F applied to the spring is shown in Fig. 2.2.

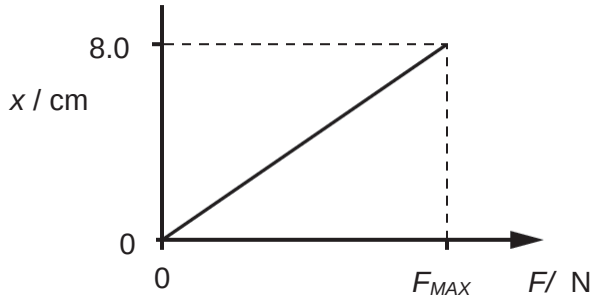

Fig. 2.2

Use your answers in **(a)** to determine the maximum force F_{MAX} exerted on the spring by the block.

F_{MAX} = …….. N [1]

(c) Calculate the maximum deceleration of the block.

decceleration = …….. m s^{-2} [1]

(d) State and explain whether the block is in equilibrium when its speed becomes zero.

……

……..[1]

(e) The length of the spring is then cut in half. The same block travelling at the same speed of 0.30 m s^{-1} hits the spring.

Suggest and explain the change, if any, on the length of compression of the spring when the speed of the block becomes zero.

……

……

……..[2]

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(f) The mass m of the block is now varied. The initial speed of the block remains constant and the spring continues to obey Hooke's law.

On Fig. 2.3, sketch the variation with mass m of the maximum compression x_0 of the spring. [2]



Fig. 2.3

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3 Body A of mass 6.5 kg is connected to body B of mass 9.5 kg by a light inextensible string that passes over a frictionless pulley. The other end of body A is connected to a light spring of spring constant k equals to 200 N m^{-1}.

At the equilibrium position, the spring is compressed and body A is 20.0 cm above the floor as shown in Fig. 3.1, with the smooth incline making an angle of 40^0 to the horizontal.

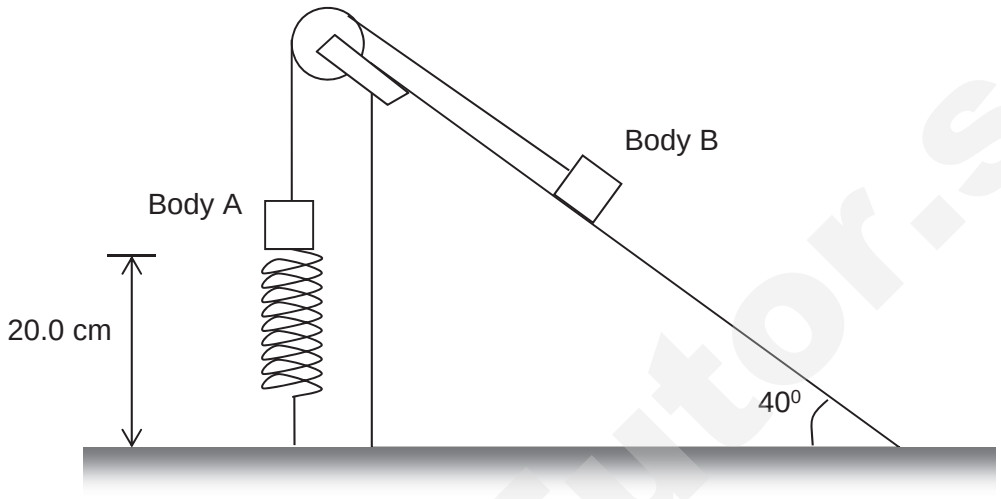

Fig. 3.1

(a) Draw the free body diagrams for A and B separately when the two bodies are in its equilibrium position. Indicate clearly the forces on your diagrams.

[4]

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(b) Body B is now given a slight displacement x down the slope and released. Show that its acceleration a is given by

$$a = - 12.5x.$$

[2]

(c) Given that x in **(b)** is 2.0 cm, determine the speed of body A when it is 21.0 cm above the floor.

speed of body A = ... m s^{-1} [1]

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4 **(a)** Describe the basic difference between the following terms. You may use diagrams to illustrate your answers.

(i) a *transverse* wave and a *longitudinal* wave,

.....

.....

.....[2]

(ii) a *polarised* wave and a *non-polarised* wave,

.....

.....

.....[2]

(iii) a *stationary* wave and a *progressive* wave.

.....

.....

.....[2]

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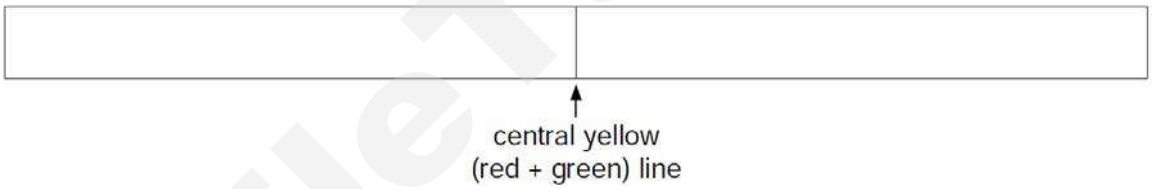
(b) Red and green light of wavelengths 640 nm and 520 nm respectively, are simultaneously directed through a diffraction grating. The grating is at right angles to the light and has a line spacing of 1.60 μm.

(i) Complete the table by calculating the values for all the angles of maxima for both colours. [2]

order, n	angle for red maximum / °	angle for green maximum / °
0	0	0
1		
2		
3	-	

(ii) On Fig. 4.1, sketch the approximate pattern that would be seen on a screen behind the diffraction grating. Label the red and green maxima with **R** and **G**, respectively.



[2]

Fig. 4.1

(iii) The grating is replaced with a double slit of the same spacing. Ignoring the change in intensity, describe how the new pattern produced differs from the one for the diffraction grating.

……

……

……

……..[3]

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5 **(a)** There is a current of 6.0 A through a component for 200 s. Calculate

(i) the charge which flows past a point in the component during this time,

charge = …… C [1]

(ii) the number of electrons which pass the point during this time.

number = …… [1]

(b) A student wanted to light a lamp, but only had available a 12 V battery of negligible internal resistance. In order to reduce the battery voltage, he connected the circuit as shown in Fig. 5.1. The maximum value of the resistance of the rheostat XY was 1000 Ω.

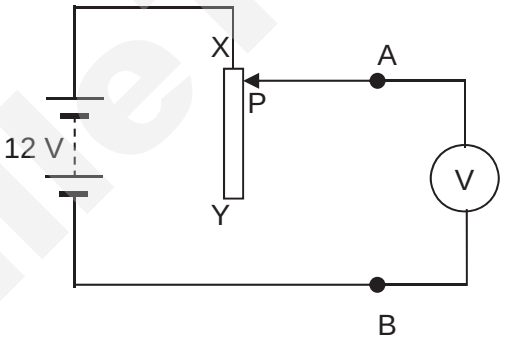

Fig. 5.1

He found that, when the sliding contact P of the rheostat was moved down from X to Y, the voltmeter reading dropped from 12 V to 11 V. Calculate the resistance of the voltmeter.

resistance = ... Ω [2]

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(c) He modified the above circuit into the one shown in Fig. 5.2 below, using the rheostat as a potentiometer, and was now able to adjust the rheostat to give a voltmeter reading of 3.0 V.

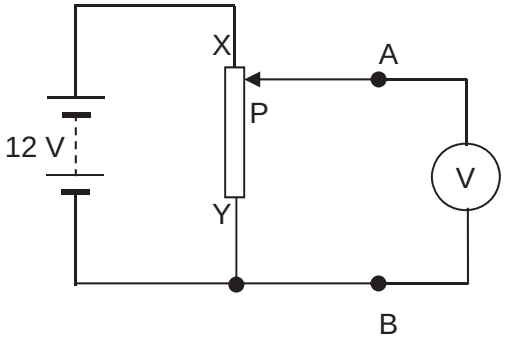

Fig. 5.2

(i) Calculate the current that flows through the voltmeter.

current = ... A [1]

(ii) Assuming that the current in **(i)** is negligible compared with the current through the rheostat, determine how far down from X the sliding contact P would have been moved. Express your answer as a fraction of the length of XY.

fraction of the length of XY = ...[2]

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(iii) The student then removed the voltmeter in Fig.5.2 and then connected a lamp rated at 0.60 W, 3.0 V in its place, but it was very dim. With reference to the power delivered to the lamp, explain quantitatively this observation.

……

……

……

……

……

……

……[4]

6 **(a)** An electron travelling with a speed of 1.55×10^6 m s^{-1} enters at an angle of 30° to a magnetic field of flux density 0.45 mT. Determine

(i) the time taken by the electron to complete a circular path,

time taken = …….. s [3]

(ii) the distance travelled by the electron along the direction of the field when it circulates once in the field.

distance travelled = …… m [2]

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(b) A small bar magnet is suspended 5.0 cm away from a long straight wire which is orientated in a north-south direction. The magnet is on the right side of the wire. When there is no current in the wire, the north pole of the magnet dips at an angle of 5.0° below the horizontal, as shown in Fig. 6.1.

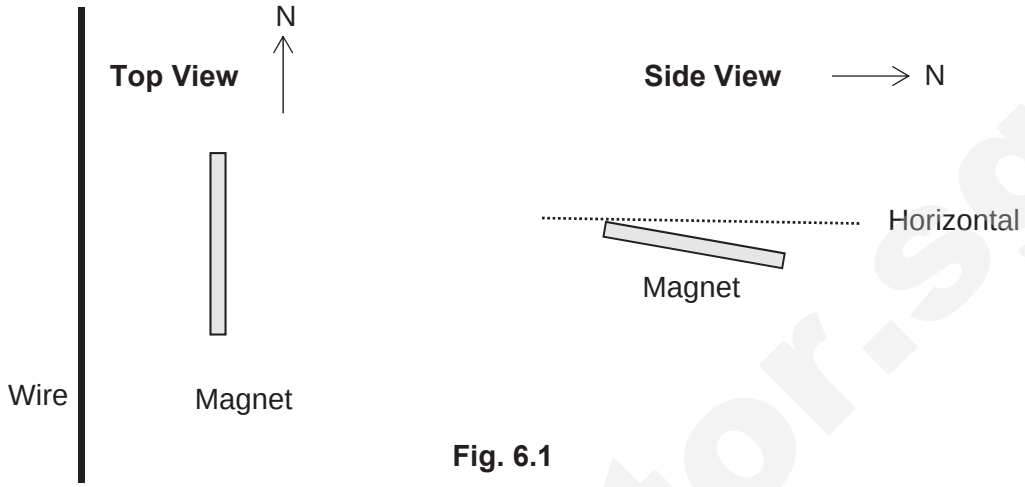

Fig. 6.1

A current is then supplied to the wire to move the magnet back to the horizontal position. Determine the magnitude and the direction of the current required.

The Earth's magnetic field in the region around the magnet is 0.17 mT.

direction = ……

magnitude = …….. A [3]

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7 A photo-multiplier converts the energy of photons of light into an electric signal. Fig. 7.1 below shows the structure of a photo-multiplier that contains nine electrodes, called dynodes, within a vacuum tube. When light is incident on the cathode, it causes photoelectrons to be emitted. These electrons are accelerated and strike the first dynode from which 6 electrons are ejected for every incident electron. These 6 electrons are accelerated to a second dynode, so producing 36 electrons, which are all accelerated to the third dynode, and so on.

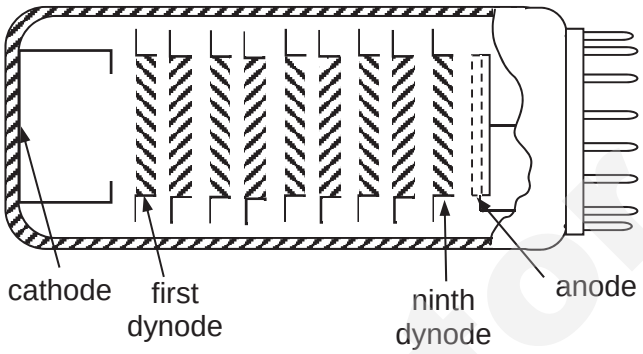

Fig. 7.1

(a) If the electrons from the ninth dynode are collected and constitute a current of 6.3 μA, show that the rate at which photoelectrons are ejected from the cathode is 3.9×10^6 s^{-1}.

[3]

(b) The incident light has a wavelength of 400 nm. At this wavelength, one in three of the incident photons ejects an electron from the cathode. Calculate the power of the incident beam.

power = …….. W [3]

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8 Resistivity and Temperature

Temperature generally affects current in an electrical circuit by changing the speed at which the charge carriers travel. In metals, this is due to an increase in resistance of the circuit that results from the increase in temperature. The opposite effect is seen in semiconductor materials where an increased temperature results in a decrease in resistance due to a change in the number of charge carriers.

Over a limited temperature range, the resistivity of different materials varies linearly with temperature according to the expression

$$\rho = \rho_0[1+\alpha(T - T_0)]$$

where ρ is the resistivity at some temperature T (in degrees Celsius), ρ_0 is the resistivity at the reference temperature T_0 = 20°C, and α is a constant called the temperature coefficient of resistivity.

The resistivity at 20°C and the temperature coefficients of resistivity for some materials are shown in the table of Fig. 8.1 below.

Material	ρ_0 / Ω m	α / °C^{-1}
Gold	2.44×10^{-8}	3.4×10^{-3}
Tungsten	5.60×10^{-8}	4.5×10^{-3}
Silver	1.59×10^{-8}	3.8×10^{-3}
Platinum	11.0×10^{-8}	3.9×10^{-3}
X	1.50×10^{-6}	0.40×10^{-3}
Y	10.0×10^{-8}	5.0×10^{-3}

Fig. 8.1

(a) Distinguish between electrical *resistance* and *resistivity.*

……

……

……

……

……[3]

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(b) Explain why the resistance of metals increases with temperature.

……

……

……[2]

(c) Calculate the resistivity, at 120°C, of

(i) gold

resistivity = …… Ω m [1]

(ii) tungsten

resistivity = …… Ω m [1]

(d) A 5.0 cm length of gold wire, of diameter 0.240 mm, is soldered to a 5.0 cm length of tungsten wire, of diameter 0.140 mm, to form a composite wire, in the configuration as shown in Fig. 8.2.

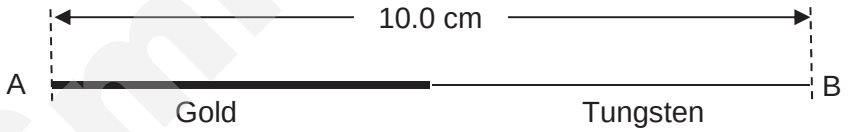

Fig. 8.2

(i) Calculate the resistance across A and B at a temperature of 120°C.

resistance = …… Ω [3]

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(ii) The composite wire in Fig 8.2 is now bent into a square loop, as shown in Fig. 8.3.

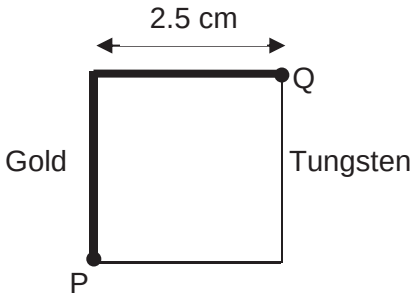

Fig 8.3

Calculate the resistance across P and Q at a temperature of 120°C.

resistance = …… Ω [2]

(e) A student would like to make an electric kettle with a coil of wire made from either material **X** or **Y**. Suggest with a reason which material, **X** or **Y**, is more suitable to be used as a heating element in an electric kettle.

……

……

……[1]

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(f) (i) Fig. 8.4 shows the variation with temperature T of the resistivity ρ of another material, Germanium. Draw the line of best fit. [1]

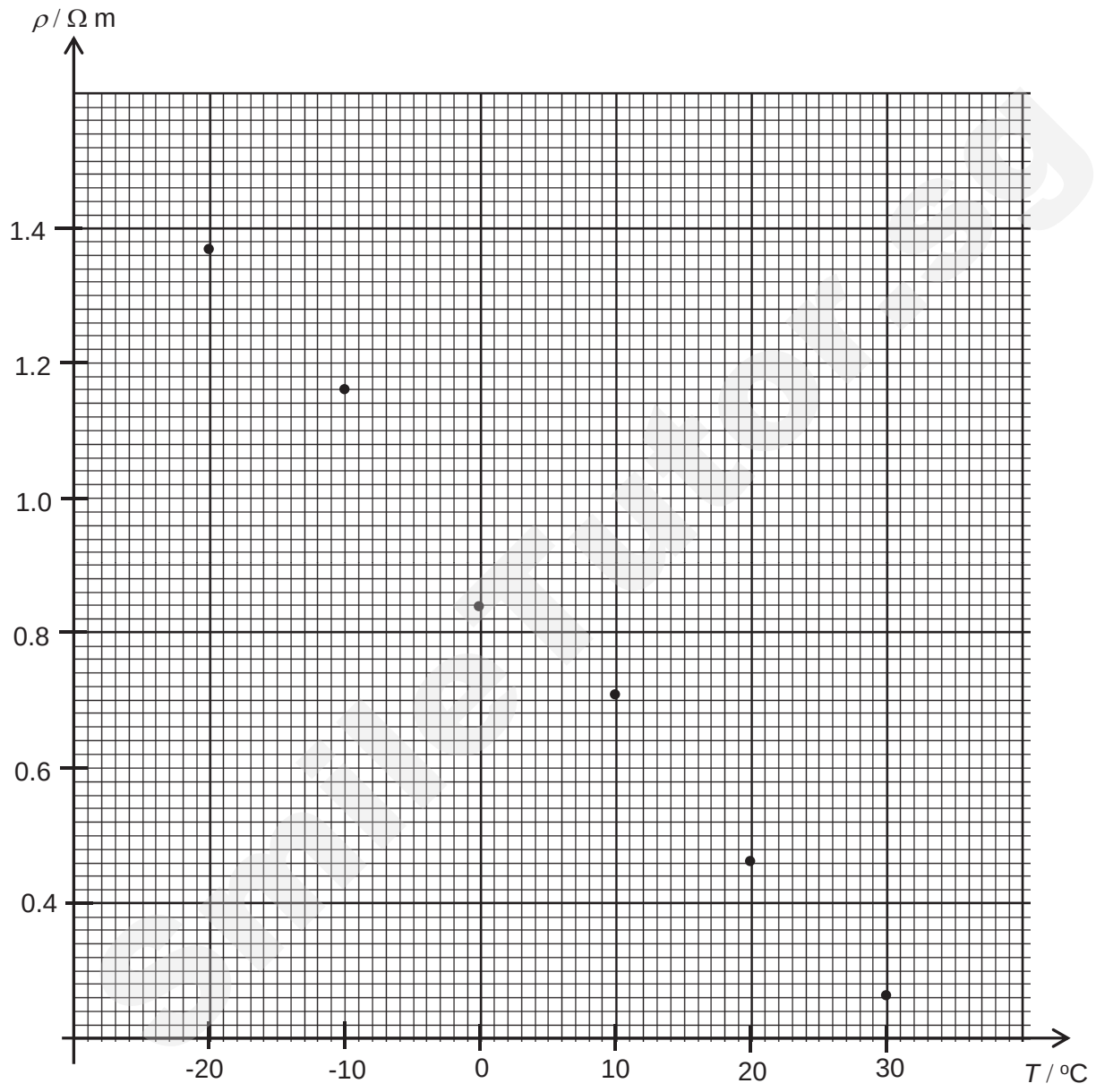

Fig. 8.4

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(ii) Use Fig 8.4 to determine the constants ρ_0 and α for germanium.

ρ_0 = ... Ω m

α = ... $^oC^{-1}$ [4]

(iii) Using your answers from **(ii)**, state and explain whether germanium is a conductor, semiconductor or an insulator.

.....

.....

.....

.....

.....[2]

END OF PAPER

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DUNMAN HIGH SCHOOL
Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9749/03

Paper 3 Longer Structured Questions

20 September 2017

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	/8
2	/10
3	/7
4	/8
5	/10
6	/9
7	/8
8	/20
9	/20
Total	/80

This document consists of **25** printed pages and **1** blank page.

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Data

speed of light in free space,	c =	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0 =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0 =	8.85×10^{-12} F m^{-1}
		$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

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Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	$T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux denxity due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in the spaces provided.

1 A cylindrical container is filled full to the brim with a liquid of density ρ = 8.0 kg m^{-3}. It is placed on a weighing scale and registered a weight W = 100 N. A rigid sphere (which would float on the liquid if allowed to do so) of volume V_s = 0.40 m^3 and mass m_s = 0.50 kg is pushed gently down and held beneath the surface of the liquid with a rigid rod of negligible volume, as shown in Fig. 1.1.

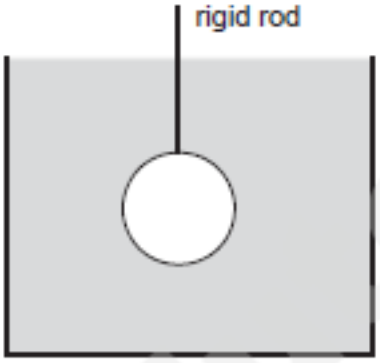

Fig. 1.1

(a) (i) Calculate the weight of liquid which overflowed when the sphere is fully submerged in the liquid.

weight = ... N [2]

(ii) Hence determine the reading on the scale.

reading = ... N [2]

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(b) If instead of being pushed down by a rod, the sphere is held in place by a thin string attached to the bottom of the container as shown in Fig. 1.2.

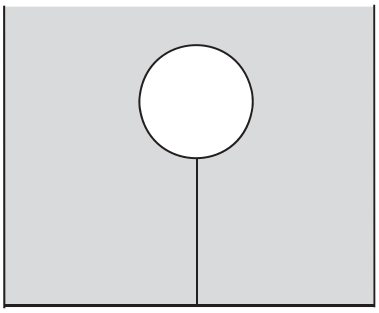

Fig. 1.2

(i) Calculate the tension in the string.

tension = ……..... N [2]

(ii) Determine the new reading on the scale.

reading = ……..... N [2]

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2 **(a)** Define *gravitational potential*.

……

…… [1]

(b) Explain why values of gravitational potential near to an isolated mass are all negative.

……

……

……

…… [2]

(c) The Earth completes one orbit around the Sun in one year. Saturn takes 29.5 years to complete an orbit around the Sun.
The distance of the Earth from the Sun is 1.50×10^{11} m.

(i) Calculate the distance of the Saturn from the Sun. Assume that both orbits are circular.

distance = ……..... m [2]

(ii) State the other main assumption you have had to make in order to answer **(c) (i)**.

……

……

…… [1]

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(d) The Sun rotates about its axis with a period of 23.4 days. A satellite is placed so that it orbits the Sun with the same angular speed as that of the Sun's rotation.

The mass of the Sun is 1.99×10^{30} kg.

Determine the distance of the satellite from the Sun.

distance = ... m [2]

(e) It is then required to reposition the satellite at an orbit closer to the Sun than that in **(d)**. State and explain whether the work done on the satellite is positive, negative or zero to change the position of the satellite to a lower orbit.

.....

.....

.....

..... [2]

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3 The volume of some air, assumed to be an ideal gas, in the cylinder of a car engine is 540 cm^3 at a pressure of 1.1×10^5 Pa and a temperature of 27 °C. The air is suddenly compressed to a volume of 30 cm^3. The pressure rises to 6.5×10^6 Pa.

(a) Determine the temperature of the gas after the compression.

temperature = ……..... °C [2]

(b) (i) State the *first law of thermodynamics*.

……

……

…… [1]

(ii) Use the law in **(b) (i)** to explain why the temperature of the air changed during the compression.

……

……

……

……

……

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……

……

…… [4]

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4 **(a)** State the evidence for the assumption that

(i) there are significant forces of attraction between molecules in the solid state,

.....

.....

..... [1]

(ii) the forces of attraction between molecules in a gas are negligible.

.....

.....

..... [1]

(b) Explain, on the basis of the kinetic model of gases, the pressure exerted by a gas.

.....

.....

.....

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.....

..... [3]

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(c) A cylinder contains 1.0 mol of a monatomic ideal gas.

(i) The volume of the cylinder is constant.
Calculate the energy required to raise the temperature of the gas by 1.0 K.

energy = ……..... J [1]

(ii) The volume of the cylinder is now allowed to increase so that the gas remains at constant pressure when it is heated.

Explain whether the energy required to raise the temperature of the gas by 1.0 K is now different from your answer in **(c) (i)**.

……

……

……

……

…… [2]

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5 **(a)** A metal sphere, A, is connected by a long fine wire to a source of potential of 900 V. An insulated stand supports the sphere sufficiently far above the bench for the effect of the latter to be negligible.

(i) The potential at 300 mm from the centre of the sphere is 450 V. Determine

1. the radius of the sphere,

radius = ……..... mm [1]

2. the charge on the sphere.

charge = ……..... C [2]

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(b) Another identical metal sphere, B, connected to the same source, is similarly supported with its centre 600 mm from that of the first sphere, A, as shown in Fig. 5.1.

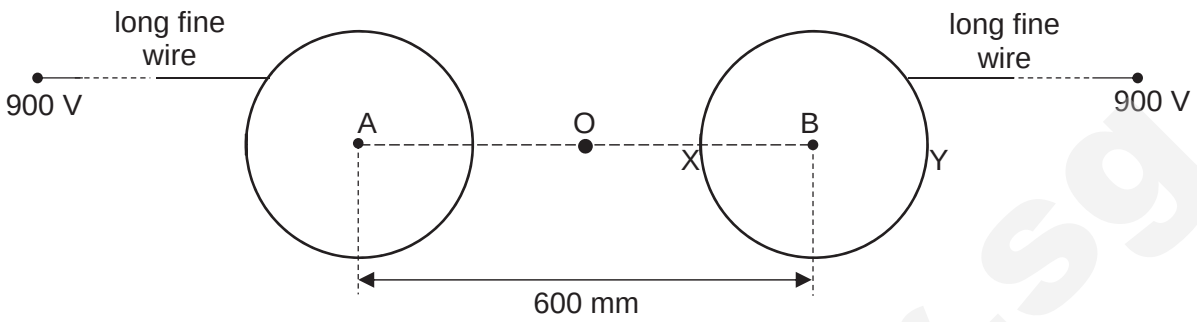

Fig. 5.1

Explain whether the electric potential at O, a point midway between the centres of A and B, is equal to, greater than, or less than 900 V.

.....

.....

.....

..... [2]

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(c) Suppose the metal spheres in **(b)** were replaced by insulating spheres which separately had a uniform surface charge density so that the electric potential on the surface of each sphere was 900 V. The spheres are then brought close to each other, as shown in Fig. 5.2. These spheres are no longer connected to any source of charge.

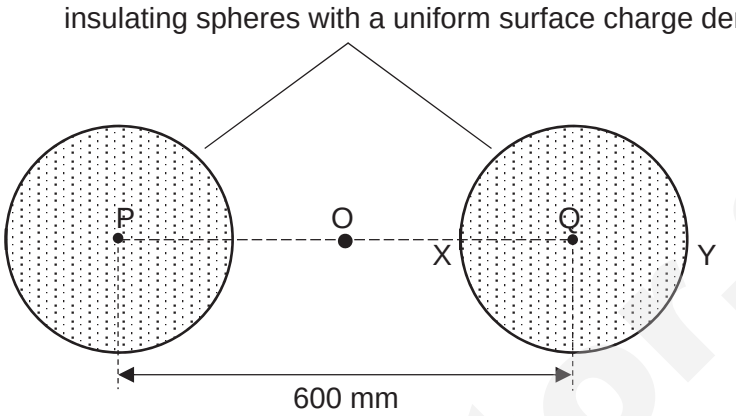

Fig. 5.2

(i) Determine the potential at X and Y on the nearer and far surface of sphere Q.

potential at X = ……..... V

potential at Y = ……..... V [3]

(ii) Explain if any electric field exists in the sphere Q.

……

……

……

…… [2]

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For Examiner's Use

6 **(a)** Distinguish between the peak value and root-mean-square value of an alternating current.

.....

.....

.....

..... [2]

(b) Express the V_{rms} of the half rectified sinusoidal voltages shown in Fig. 6.1 in terms of V_0.

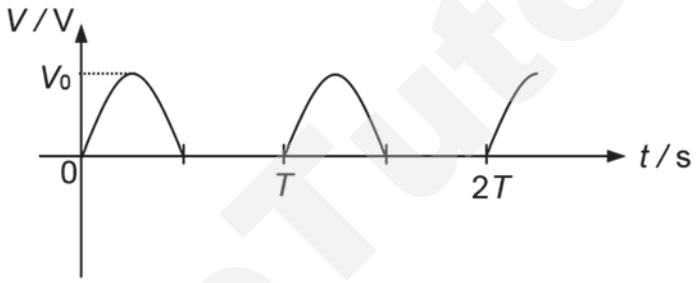

Fig. 6.1

V_{rms} = ... V [2]

(c) A power station needs to deliver 20.0 MW of power to a city 10.0 km away. This power is generated at 16.0 kV and then stepped up to 240 kV using a transformer before transmission. The resistance per unit length of the transmission cables is 20.0 Ω km^{-1}. The operator of the station loses \$0.10 for every kWh of electrical power lost.

(i) Calculate the power lost during transmission.

power lost = ... W [2]

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(ii) Hence determine the amount of money saved by the station in one day by transmitting power at 240 kV instead of 16.0 kV.

money saved = $……..... [3]

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7 **(a)** When free electrons collide with atoms in their ground state, the atoms can be excited or ionised.

(i) State what is meant by *ground state*.

……

……

…… [1]

(ii) Explain the difference between *excitation* and *ionisation*.

……

……

……

……

…… [2]

(b) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

.....

.....

.....

.....

.....

..... [3]

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(c) Fig. 7.1 shows five electron energy levels in an atom and some transitions between them.

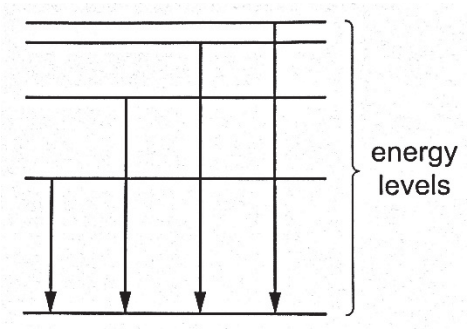

Fig. 7.1

The line spectrum produced is in the visible region of the electromagnetic spectrum.

Sketch on Fig. 7.2 the line emission spectrum corresponds to the four energy level changes, assuming that the energy levels are drawn roughly to scale.

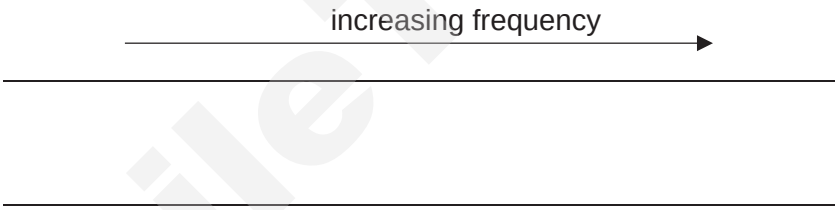

Fig. 7.2

[2]

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Section B

For Examiner's Use

Answer **one** question from this Section in the spaces provided.

8 A light spring is suspended from a fixed point. A bar magnet is attached to the end of the spring, as shown in Fig. 8.1.

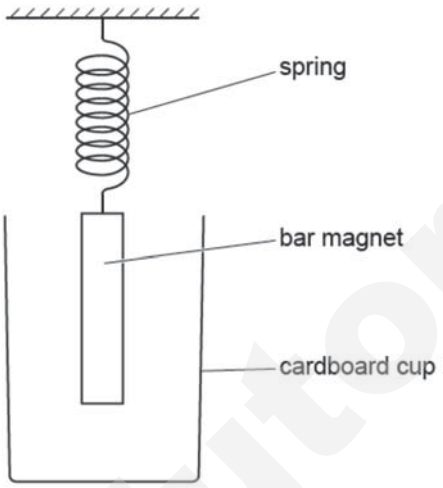

Fig. 8.1

In order to shield the magnet from draughts, a cardboard cup is placed around the magnet but does not touch it. The magnet is displaced vertically and then released. The variation with time *t* of the vertical displacement *y* of the magnet is shown in Fig. 8.2.

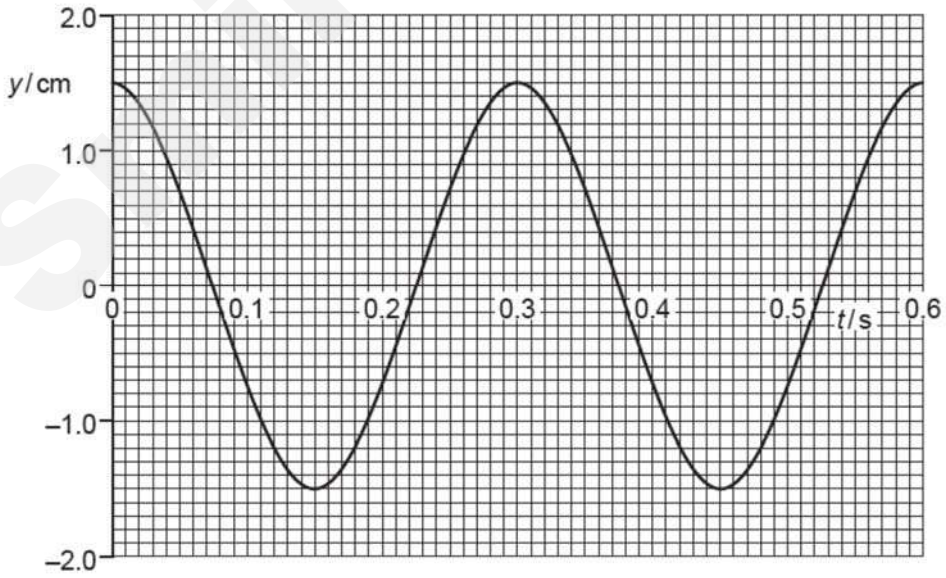

Fig. 8.2

The bar magnet undergoes simple harmonic motion with angular frequency ω.
The mass of the magnet is 130 g.

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(a) For the oscillations of the magnet, use Fig. 8.2,

(i) state the times at which the speed of the magnet is maximum.

time = ... s [1]

(ii) determine the angular frequency ω,

ω = ... rad s^{-1} [2]

(iii) calculate the maximum potential energy E of the oscillating magnet.

E = ... J [2]

(iv) Use your answer in **(a)(iii)** to sketch, on the axes of Fig. 8.3, a labelled graph of the variation with displacement y of the potential energy E of the magnet.

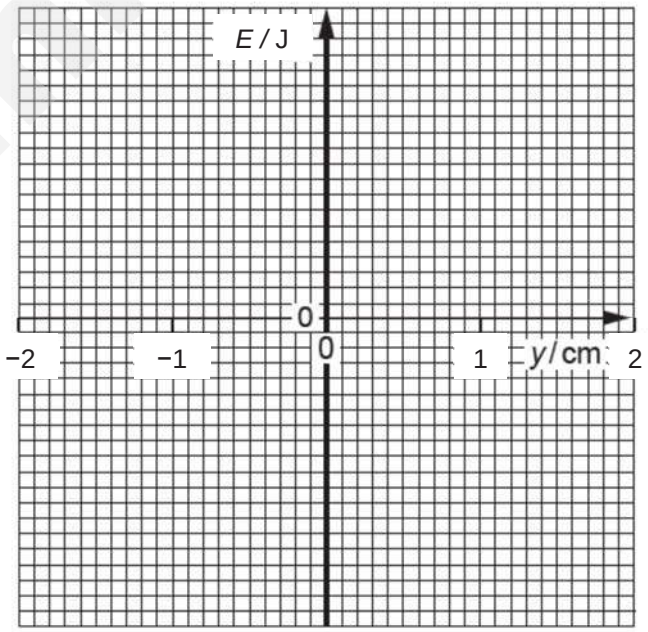

Fig. 8.3

[2]

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(b) The spring is now hung vertically to an oscillator.
When the oscillator is switched on, it produces vertical oscillations of constant amplitude but with a frequency that can be varied.

Sketch a labelled graph of the variation with frequency f of the amplitude y_0 of the oscillations of the magnet.



[2]

(c) Archaeologists use an instrument called a geophone, as shown in Fig. 8.4, to detect man-made structures under the ground.

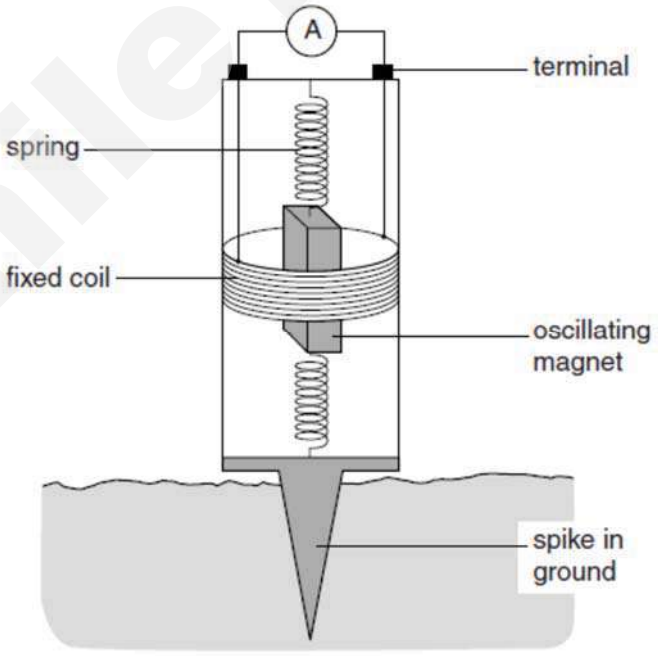

Fig. 8.4

The ground is made to vibrate. The magnet begins to oscillate within the insulated coil of wire fixed to the casing of the geophone. An e.m.f. is induced in the coil, producing a current which is measured by the ammeter.

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(i) The coil has 60 turns. The maximum e.m.f. induced in this geophone is 84 mV. Calculate the maximum rate of change of flux linkage in the coil. Give units with your answer.

maximum rate of change of flux linkage = ……..... [3]

(ii) The relationship needed to answer part **(c) (i)** is a mathematical expression of Faraday's law.

State Faraday's law in words only.

……

……

…… [1]

(iii) Eventually the relative motion of the coil and magnet ceases due to damping. Briefly explain how this damping effect is consistent with Lenz's law.

……

……

……

……

……

……

…… [4]

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(d) On the axes of Fig. 8.5, sketch a graph of variation with time t of displacement y of the magnet for 3 complete oscillations of the damped motion. Numerical values are not required.

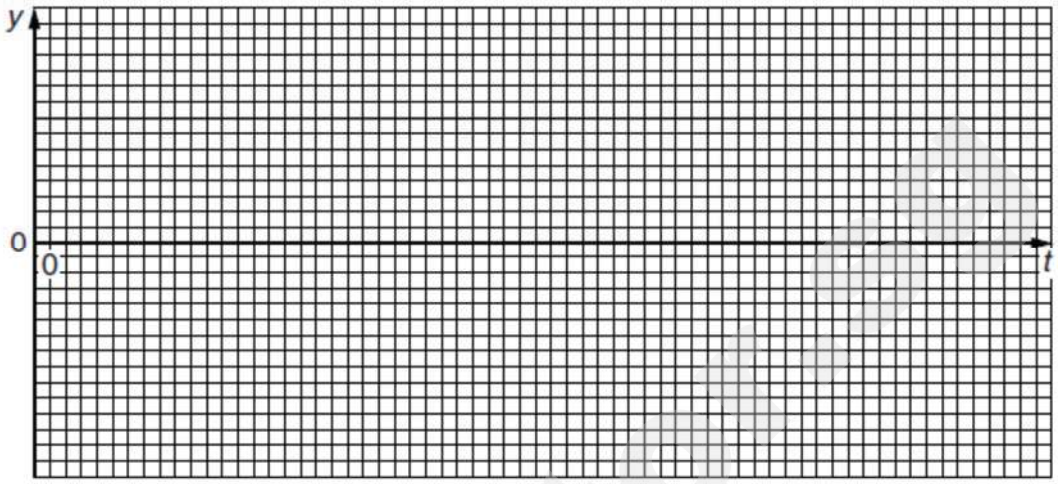

Fig. 8.5

[3]

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9 **(a)** Define the *binding energy* of a nucleus.

.....

.....

..... [2]

(b) A stationary nucleus of uranium-238 ($^{238}_{92}U$) decays to form a nucleus of thorium-234 ($^{234}_{90}Th$). An α-particle and a gamma-ray photon are emitted. The equation representing the decay is

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + \gamma$$

The binding energy per nucleon *E* of the nuclei are given in Fig. 9.1.

nucleus	*E* / MeV
uranium-238	7.570
thorium-234	7.597
helium-4	7.075

Fig. 9.1

(i) State the relationship between the binding energies of the nuclei that is consistent with this reaction being energetically possible.

.....

.....

..... [1]

(ii) Calculate, for this reaction, the total energy, in J, released.

energy = ... J [2]

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(iii) State and explain whether the energy of the gamma-ray photon is equal to the energy released in the reaction.

.....

.....

.....

..... [2]

(c) When beryllium is bombarded with α-particles of energy 8.0×10^{-13} J, carbon atoms are produced, together with a very penetrating radiation. The nuclear reaction might be

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{13}_{6}\text{C} + \gamma$$

The energy of the penetrating radiation is found to be at least 8.8×10^{-12} J for each γ produced.

The masses of the nuclei are given in Fig. 9.2.

nucleus	mass / u
$^{9}_{4}$Be	9.0150
$^{4}_{2}$He	4.0040
$^{13}_{6}$C	13.0075

Fig. 9.2

For the nuclear reaction, determine the total energy, in J,

(i) before the nuclear reaction,

energy = ... J [2]

(ii) after the nuclear reaction.

energy = ... J [2]

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(iii) Hence, explain why the reaction is not possible.

……

…… [1]

(d) (i) The arrival of particles at a Geiger tube from a radioactive substance is said to be random. Describe what '*random*' means in this context.

……

……

…… [2]

(ii) A student stated that 'radioactive materials with a short half-life always have a high activity'. Discuss whether the student's statement is valid.

……

……

……

…… [2]

(iii) Some radioactive nuclides have very long half-lives. For example, Uranium-238 has a half-life of 4.5×10^9 years. Outline an experimental method to determine the half-life of the Uranium-238 nuclide.

……

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……

……

…… [4]

END OF PAPER

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Dunman High School Year 6 Prelim Exam 2017 H2 Physics Answers

Paper 1 (/30 marks)

1. B	2. B	3. C	4. C	5. D	6. C	7. C	8. B	9. D	10. D
11. C	12. D	13. B	14. C	15. D	16. D	17. D	18. D	19. C	20. C
21. C	22. A	23. A	24. A	25. D	26. A	27. B	28. B	29. B	30. B

Paper 2 (/80 marks)

1 (a) (i) Weight of monkey and (frictional) force by rope on monkey
Or Weight of monkey and tension of rope on monkey A1

(ii) Monkey climbs up so force by monkey on rope > 20g B1
(Frictionless pulley) tension in the rope is the same on the monkey and on the bananas M1
Bananas move up. A1

(iii) Start at rest with same upwards acceleration, distance is a constant. A1

(b) Bananas slow down at the same rate as that of monkey (same magnitude of force on monkey and bananas). M1
Bananas also come to a complete stop at the same time as that of monkey. A1

2 (a) $E_k = ½ mv^2 = ½ \times 0.40 \times 0.30^2 = 1.8 \times 10^{-2}$ J A1

(b) loss in KE = gain in EPE
$1.8 \times 10^{-2} = ½ \times F \times 0.080$
$F_{MAX} = 0.45$ N A1

(c) $a = F/m = 0.45 / 0.40 = 1.1$ m s^{-2} A1

(d) Resultant force is not zero (F_{MAX} acting on block), so not in equilibrium. A1

(e) spring constant increases (by 2 times) M1
maximum compression reduces (is now 5.7 cm) A1

(f) Curved line from origin, B1
With decreasing gradient (no plateau) B1

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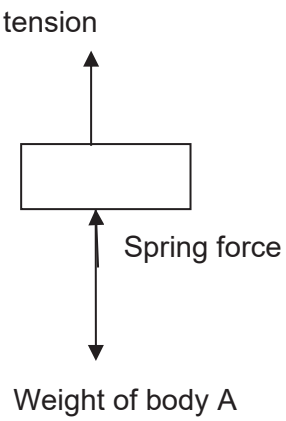
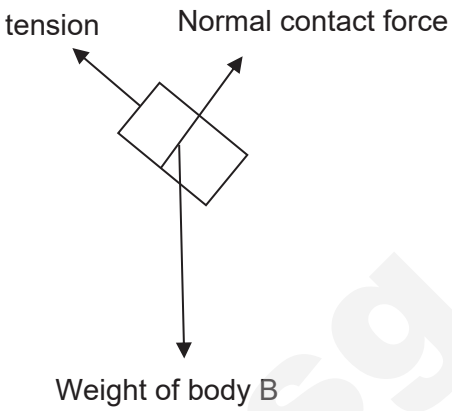
3 (a)





For the two free bodies each:
Correct label of all forces B1
Correct magnitude shown in the length drawn for all forces B1 Total: 4 marks

(b) Restoring Force, $F_{restoring} = -kx = -200x$ M1

Consider body A and body B as one system,

$F_{net} = F_{restoring} = -200x = (m_A + m_B)a$ M1

$a = -200x/(m_A + m_B) = -200x/(6.5 + 9.5) = -12.5x$ A0

(c)

$$v = \omega\sqrt{x_0^2 - x^2}$$
$$v = \sqrt{12.5}\sqrt{0.020^2 - 0.010^2}$$
$$= 0.0612 \text{ ms}^{-1}$$ A1

4 (a) (i) transverse wave has vibrations perpendicular/normal to direction of energy travel B1
longitudinal wave has vibrations parallel to the direction of energy travel B1
accept answers in terms of a diagram

(ii) polarised with all vibrations in a single axis / direction
(normal to direction of energy travel) B1
non-polarised with vibrations in all directions B1
a diagram here must have at least three doubled headed arrows.

(iii) progressive: all particles have same amplitude
stationary: maximum (antinode) to minimum/zero amplitude (node) B1
progressive: adjacent particles are not in phase
stationary: wave particles are in phase (between adjacent nodes) B1
progressive: transfer energy
stationary: do not transfer energy B1
(max 2 marks)

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(b) (i)

	red / °	green / °
0	0	0
1	23.6	19.0
2	53	40.5
3	–	77.2

all correct 2 marks
1 wrong, 1 mark.
More than 1 wrong, 0 mark

(b) (ii) One side correct (GRGRG) B1
Same on both sides B1

(iii) Fuzzy pattern instead of sharp B1
Any two from: B2
Red bands wider than green bands
Red bands wider apart than green bands
Some yellow bands where they overlap
Equally spaced maxima/minima/fringes

5(a) (i) $Q = It = (6.0)(200) = 1200\ \text{C}$ B1

(ii) $N = Q/e = 1200/(1.60\times10^{-19}) = 7.5\times10^{21}$ B1

(b)

Let the voltmeter resistance be R_V.

When the sliding contact P was at Y, potential divider rule gives:

$$\left(\frac{R_V}{R_V + 1000}\right)(12\ \text{V}) = 11\ \text{V}$$ B1

$\Rightarrow R_V = 11\ \text{k}\Omega$ A1

OR

Current through XY $= 1/1000$ A. B1

$$R_V = \frac{11}{1/1000} = 11\ \text{k}\Omega$$ A1

(c) (i)

$I_V = 3\ \text{V}/11\ \text{k}\Omega$

$= 0.27\ \text{mA}$ A1

(ii) Position of slider has to be such that $\frac{\text{PY}}{\text{XY}} = \frac{3\ \text{V}}{12\ \text{V}} = \frac{1}{4}$ C1

Sliding contact would have been moved down 3/4 of its length from X. B1

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(iii) resistance of lamp = $V^2/P = (3.0)^2/0.60 = 15\ \Omega$

effective resistance across AB, $R_{AB} = \dfrac{15 \times 250}{15 + 250} = \underline{14.2\ \Omega}$ B1

p.d. across AB, $V_{AB} = (12)\left(\dfrac{R_{AB}}{R_{AB} + 750}\right) = \underline{0.222\ \text{V}}$ B1

power delivered to the lamp $= \dfrac{V_{AB}^{\ 2}}{15\ \Omega} = \underline{0.0033\ \text{W}}$ M1

[OR

current from power supply, $I = \dfrac{12}{(750 + R_{AB})} = 0.0157$ A,

current through lamp, $I_{lamp} = I\left(\dfrac{250}{250 + 15}\right) = 0.0157\left(\dfrac{250}{250 + 15}\right) = \underline{0.0148\ \text{A}}$, B1

power delivered to the lamp $= I_{lamp} V_{AB}$ or $I_{lamp}^{\ 2}(15) = \underline{0.0033\ \text{W}}$ M1]

This is only 0.55% of 0.6 W. Since this is much lower than 0.6 W, its brightness is very low. A1

6 (a) (i)

$$Bqv = \frac{mv^2}{r}$$

$$r = \frac{mv}{eB} = \frac{(9.11x10^{-31})(1.55x10^{6})}{(1.6x10^{-19})(0.45x10^{-3})}$$ M1

$= 1.96x\ 10^{-2}$ m A1

$$T = \frac{2\pi r}{v}$$

$$= \frac{2\pi(1.96x10^{-2})}{(1.55x10^{6})}$$

$= 7.95 \times 10^{-8}$ s A1

(ii) Distance traveled $= (1.55 \times 10^{6})\cos 30^{0}(7.95 \times 10^{-8})$ M1

$= 0.107$ m A1

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(b) The north pole of the magnet indicates the direction of the Earth's magnetic field which points at an angle of 5^0 below the horizontal.

Vertical component of Earth's magnetic field, *B* downwards

$= 0.17x10^{-3} \sin 5^o$

$= 1.48 \times 10^{-5}\ T$ C1

To orientate the magnet horizontally, the magnetic field due to the wire must neutralise the downward field due to the Earth.

$$B = \frac{\mu_o I}{2\pi r} = \frac{4\pi x 10^{-7} I}{2\pi(5.0x10^{-2})} = 1.48 \times 10^{-5}\ T = 3.7\ A \quad \text{M1}$$

in the north-south direction A1

7 (a) No. of electrons leaving 9th dynode = $6^9 = 1.01 \times 10^7$ ----------[B1]

Rate at which photoelectrons are collected at 9th dynode to produce 6.3 μA,

$$\left(\frac{dn}{dt}\right)_{collected} = \frac{6.3\times10^{-6}}{1.6\times10^{-19}} = 3.9375\times10^{13}\ s^{-1}$$ ----------[B1]

Rate at which photoelectrons are ejected from cathode,

$$\left(\frac{dn}{dt}\right)_{ejected} = \frac{3.9375\times10^{13}}{1.01\times10^{7}} = 3.9\times10^{6}\ s^{-1}$$ (shown) ----------[B1]

(b) Rate at which photons are incident on cathode,

$\frac{N_{photon}}{t}$ = 3 x Rate at which photoelectrons are ejected C1

$= 3\ (3.9 \times 10^6)$

$= 1.17 \times 10^7\ s^{-1}$

$$P = \frac{N_{photon} h c/\lambda}{t} = \frac{1.17 \times 10^7 \times 6.63 \times 10^{-34} \times 3.0 \times 10^8}{400 \times 10^{-9}}$$ M1

$= 5.82 \times 10^{-12}$ W A1

8 (a)

The resistance R **of a conductor is defined as the ratio** $\frac{V}{I}$ where V is the potential difference across the conductor and I is the current flowing through it. ----------[B1]

Resistivity is a relationship between the dimensions of a specimen of a material and its resistance that is constant at constant temperature and determined by $\rho = \frac{RA}{L}$ where *R* is resistance, *A* is cross-sectional area and *L* is length. ----------[B1]

Resistance is a property of the sample (depends on the dimensions of the sample) whereas resistivity relates to the material. ----------[B1]

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(b) lattice vibrations increases ---------- [M1]
Resulting in lower drift velocity of the charge carriers (electrons) ----------[A1]

(c) (i) 3.27×10^{-8} Ωm -----[A1]
(ii) 8.12×10^{-8} Ωm -----[A1]

(d) (i) The 2 wires are in series, thus effective resistance adds up.
Resistance

$$= R_{gold,120\deg} + R_{tungsten,120\deg}$$

$$= \frac{(3.27\times10^{-8})(0.050)}{\pi(\frac{0.240\times10^{-3}}{2})^2} + \frac{(8.12\times10^{-8})(0.050)}{\pi(\frac{0.140\times10^{-3}}{2})^2}$$ ----[M2, A1]

$$= 0.03614 + 0.26374 = 0.300\Omega$$

(d)(ii) The 2 wires are in parallel,

$$R = (1/R_{gold,120\deg} + 1/R_{tungsten,120\deg})^{-1}$$

$$= (\frac{1}{0.03614} + \frac{1}{0.26374})^{-1} = 0.0318\Omega$$ -----[M1,A1]

(e) Material X is more suitable, as it has a larger resistivity. Thus for the same resistance in the heating element, a shorter length of X is required compared to Y.
OR
Material X is a more suitable material. It has a much smaller temperature coefficient of resistivity α than material Y. The resistance of X and hence the power output will be relatively more constant compared to Y during heating. ---[B1]

(f) (i) best fit line drawn and anomalous point identified correctly. -----[B1]

(ii) linearising equation and deriving expressions that equate gradient and y-intercept [C1]
gradient calculated correctly. Read offs must be accurate to half a small square. [C1]
ρ_0 = (0.4 to 0.6) Ω m [A1]
α = -(0.04 to 0.06) $^oC^{-1}$ [A1]

(iii) A negative temperature coefficient of resistivity indicates that the resistivity of Germanium decreases with increasing temperature. [M1]
Germanium is a semiconductor. [A1]

Paper 3 (/80 marks)

1 (a) (i) Weight of liquid overflowed = density of liquid x volume of liquid overflowed x g
= ρ V_s g C1
= 8.0 x 0.40 x 9.81 = 31.4 N = 31 N A1

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(ii) Upthrust (force by liquid on sphere) = 31N
Based on Newton's Third Law, |Force by sphere on liquid| = |Upthrust| = 31N

By considering the liquid as a free body, reading on the scale is W'
W' = Original weight of fluid – weight of liquid overflowed
+ force by sphere on liquid C1
= W – ρ V_s g + ρ V_s g
= W = 100 N A1

(b) (i) T + m_sg = U C1
T = ρ V_s g – m_s g
= 31.4 – 0.5(9.81) = 26.48 N = 26 N (↓) A1

(ii) By considering the [sphere + liquid] as a free body, the new reading on the scale is W''
W'' = Original weight of liquid – weight of liquid overflowed
+ weight of sphere C1
= W – ρ V_s g + m_s g
= 100 – 31.4 + 0.5(9.81) = 73.5 = 74 N A1

2 (a) Work done per unit mass in bringing a small test mass from infinity to that point B1
(b) Forces are attractive and potential is zero at infinity M1
Work got out in moving to that point A1

(c) (i) $\frac{GMm}{r^2} = mrw^2$
$\rightarrow r^3 \propto T^2$
$\frac{r^3}{(1.50\times10^{11})^3} = \frac{29.5^2}{1^2}$ C1
r = 1.43 x 10^{12} m A1

(ii) Gravitational forces by other planets on Earth or Saturn are negligible compared to that by Sun. B1
Or Saturn and Earth are considered as point masses

(d) $\frac{GMm}{r^2} = mrw^2$
$\frac{(6.67\times10^{-11})(1.99\times10^{30})}{r^2} = r\left(\frac{2\pi}{23.4\times24\times60\times60}\right)^2$ C1
r = 2.40 x 10^{10} m A1

(e) Changing satellite to a lower orbit, the gain in KE is less than the loss in PE
Or Total Energy (TE) decreases M1
So negative work done on satellite A1

3 (a) pV/T = constant
T = (6.5 x 10^6 x 30 x 300) / (1.1 x 10^5 x 540)

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= 985 K ----------[C1]
= 712 °C ----------[A1]

(b)(i) The increase in the internal energy of a system is equal to the sum of the heat supplied to the system and the external work done on the system. [B1]

(ii) *q* is zero. ----------[B1]
W is positive and *U* increases. ----------[B1]
U increases is rise in KE of atoms since gas is ideal. ----------[M1]
Mean KE increases, hence T increases. ----------[A1]
(allow only one of the last 2 marks if states "U increases so T rises")

4 (a) (i) solid has fixed volume / fixed shape/ incompressible. ----------[B1]
(ii) gas fills any space into which it is put / compressible. ----------[B1]

(b) atoms have collisions with the walls, hence momentum of atom changes. ----[B1]
so impulse (on wall) / force on wall ----------[B1]
random motion / many collisions (per unit time) gives rise to force / pressure. ----[B1]

(c) (i) 12.5 J ----------[A1]

(ii) energy is needed to push back atmosphere /do work against atmosphere ---[M1]
So total energy required is greater ----------[A1]

5 (a) (i) 1. $V \propto \frac{1}{r} \Rightarrow (900)R = (450)(300) \Rightarrow R = 150 \text{ mm}$ B1

2.

$$900 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{(150 \text{ mm})}$$ C1

$$\Rightarrow Q = 1.5 \times 10^{-8} \text{ C}$$ A1

(b) less than 900 V B1
mutual repulsion displaces the charges toward the outer sides of the spheres
effective separation of the charges increases B1

(c)(i)

potential at X or Y = potential due to P + potential due to Q C1

$$V_X = \frac{900 \times 150}{450} + 900 = 1200 \text{ V}$$ B1

$$V_Y = \frac{900 \times 150}{750} + 900 \quad 1080 \text{ V}$$ B1

(ii) yes B1
there is an electric potential gradient B1

6 (a) Peak value is the amplitude of the a.c. signal. B1

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Root mean square value of an alternating current is equivalent to the steady direct current which dissipates heat at the same average rate in a given resistor. B1

(b)
$$V_{rms} = \sqrt{<V^2>} = \sqrt{\frac{1}{2}(\frac{V_0^2}{2})} \qquad \text{C1}$$
$$= \frac{V_0}{2} \qquad \text{C1}$$

(c)(i)
$$P_{loss} = I^2R = \left(\frac{20.0\times10^6}{240\times10^3}\right)^2 \times 20.0 \times 10 \qquad \text{M1}$$
$$= 1.39\times10^6 \text{ W} \qquad \text{A1}$$

(ii) $P_{loss} = I^2R = \left(\frac{20.0\times10^6}{16\times10^3}\right)^2 \times 20.0 \times 10 = 3.13\times10^7 \text{ W}$ M1

$$\text{Money saved} = (3.13\times10^8 - 1.39\times10^6) \times 10^{-3} \times 24 \times 0.10 \qquad \text{M1}$$
$$= \$747000 \qquad \text{A1}$$

7 (a) (i) when electrons/atoms are in their lowest energy/minimum energy/most stable (state) B1

(ii) excitation promotes an electron to a higher energy level. B1
ionization occurs when an electron receives enough energy to leave the atom. B1

(b) electrons occupy discrete energy levels / difference in energy levels are discrete. B1
energy of photon is proportional to frequency (E = hf) B1
atom/electron can be excited only when energy of photon exactly matches the difference in energy levels (1 to 1 interaction/ all energy of photon absorbed) B1

(c) 4 lines drawn. M1
Correct spacing. A1

8 (a) (i) 0.075s, 0.225s, 0.375s, 0.525s A1

(ii) $\omega = 2\pi/0.30$ M1
$= 20.9 \text{ rad s}^{-1}$ A1

(iii) maximum potential energy $= \frac{1}{2}m\omega^2 y_0^2$
$= \frac{1}{2} \times 0.130 \times 20.9^2 \times (1.5\times10^{-2})^2$ M1
$= 6.4\times10^{-3}$ J A1

(iv) Correct shape B1
Correct values of max P.E and amplitude B1

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(b) Correct values of amplitude and resonant frequency B1
Correct shape B1

(c) (i)

$$E = -\frac{dN\phi}{dt} \quad \text{M1}$$

$$\frac{dN\phi}{dt} = 84 \text{ x } 10^{-3} \text{ V} \quad \text{A1} \quad \text{C1 for correct unit}$$

(ii) The induced e.m.f is directly proportional to the rate of change of magnetic flux linkage. B1

(ii) Lenz's law is a consequence of law of conservation of energy B1
Magnetic field created by induced current in coil repels permanent magnetic field B1
Work has to be done to move the magnet through the coil because it is repelled B1
This energy is converted to electrical energy dissipated in the coil's complete circuit B1

(d) 3 complete oscillations drawn B1
Period kept constant (slight increase acceptable) B1
Reasonably symmetrical and continuous steady decrease in amplitude B1

9 **(a)** *either*
(minimum) energy required / work done to separate the nucleons (in a nucleus) M1
to infinity A1
or
energy released when nucleons come together (to form a nucleus) (M1)
from infinity (A1)

(b) **(i)** (total) binding energy of thorium and helium (nuclei) greater than binding energy of uranium (nucleus) B1

(ii) $7.597\times234 + 7.075\times4 - 7.570\times238 = 4.338$ MeV B1

$4.338\times10^{6} \times 1.60\times10^{-19}$ J = $\underline{6.941\times10^{-13}\text{ J}}$ A1

(iii) Th nucleus / He nucleus / product nucleus has kinetic energy M1
energy of gamma photon must be less than energy released A1

(c) **(i)** $(9.0150 + 4.0040) \times 1.66\times10^{-27} \times (3.00\times10^{8})^2 + 8.0\times10^{-13}$ J B1
= $\underline{1.946\times10^{-9}\text{ J}}$ A1

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(ii) $13.0075 \times 1.66\times10^{-27} \times (3.00\times10^{8})^2 + 8.8\times10^{-12}$ B1

$= \underline{1.952\times10^{-9}\ \text{J}}$ A1

(iii) the total energy after the nuclear reaction is greater than that before the reaction (violation of conservation of energy) B1

(d) **(i)** in each second there is a fixed probability that a particle will arrive, [B1]
but time of arrival of a particle cannot be predicted [B1]

(ii) $A = \left(\frac{\ln 2}{t_{1/2}}\right) N$: activity proportional to the number of unstable/undecayed nuclei present B1
short half-life radioactive material having low number of unstable nuclei can have low activity B1

(iii) <u>determine the number of atoms *N*</u> in a pure sample from the measured mass of the sample (using weighing machine) B1

use a GM tube, with effective window area *S* at a distance *x* from source, connected to a rate meter to <u>measure the count rate *C*</u> B1

<u>calculate the activity</u> $A = (4\pi x^2/S)\,C$ B1

determine decay constant λ from $A = \lambda N$,
and then determine half-life $t_{1/2}$ using equation $t_{1/2} = (\ln 2)/\lambda$ B1

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HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**16S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9749/01

Paper 1 Multiple Choice

21 September 2017

1 hour

Additional Materials: Optical Mark Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

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Data

speed of light in free space,
$c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space,
$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge,
$e = 1.60 \times 10^{-19}$ C

the Planck constant,
$h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant,
$u = 1.66 \times 10^{-27}$ kg

rest mass of electron,
$m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton,
$m_p = 1.67 \times 10^{-27}$ kg

molar gas constant,
$R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant,
$N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant,
$k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant,
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

acceleration of free fall,
$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/ by a gas, $W = p\,\Delta V$

hydrostatic pressure $p = \rho gh$

gravitational potential, $\phi = -\frac{Gm}{r}$

temperature T/K = T/ °C + 273.15

pressure of an ideal gas $P = \frac{1}{3}\frac{Nm}{V} < c^2 >$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm \omega \sqrt{(x_o^2 - x^2)}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_0 r}$

alternating current / voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire
$B = \frac{\mu_o I}{2\pi d}$

magnetic flux density due to a flat circular coil
$B = \frac{\mu_o N I}{2r}$

magnetic flux density due to a long solenoid
$B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 Which of the following is equivalent to the quantity, 37.86×10^{-4} MJ cm^{-4}?

A 37.86×10^{-18} J m^{-4}

B 37.86 μJ m^{-4}

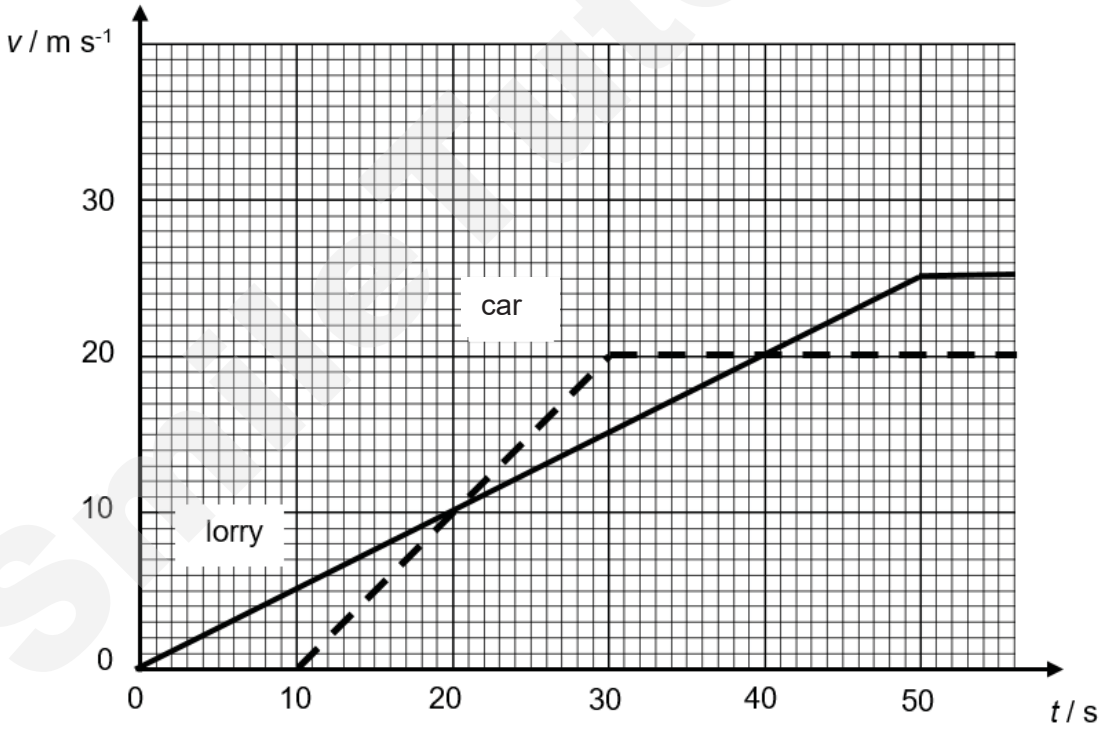
C 378.6 TJ m^{-4}

D 378.6 GJ m^{-4}

2 Which of the following is the best estimate of the population density (population per unit area) in Singapore?

A 10^{0} km^{-2} **B** 10^{2} km^{-2} **C** 10^{4} km^{-2} **D** 10^{6} km^{-2}

3 The variation with time *t* of the speed *v* of a lorry after leaving a petrol station is as shown in the graph below. A car leaves the petrol station 10.0 s later and its speed-time graph is also shown.



At which of the following times would the distance between the lorry and car be the least?

A 20.0 s **B** 30.0 s **C** 40.0 s **D** 50.0 s

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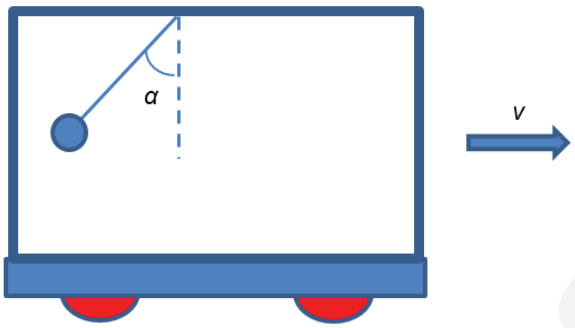
4 A mass *m* hangs at the end of a rope which is attached to a support fixed on a trolley moving to the right with a speed *v* on a horizontal track, as shown. The angle, *α*, is the angle the rope makes with the vertical.



Which of the following statements is **false**?

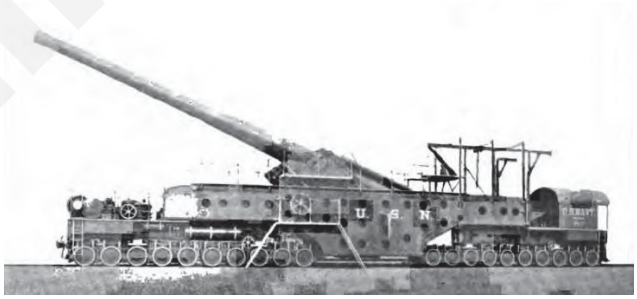
A The angle *α* is zero when the trolley moves with a uniform speed.

B When the trolley moves with a constant acceleration *a*, the magnitude of angle *α* is only determined by *a* and *g*.

C The tension *T* in the rope is larger when the trolley moves with a uniform speed than when it moves with a constant acceleration.

D The ball swings to the right when the trolley decelerates.

5 A 70 000 kg railway gun sitting on the railway platform in contact with the Earth is as shown.



It fires a 500 kg artillery shell at an angle of 45° and with a muzzle velocity of 200 m s^{-1}. What is the magnitude of the recoil velocity of the gun?

A 0.5 m s^{-1} **B** 1.0 m s^{-1} **C** 1.4 m s^{-1} **D** 2.8 m s^{-1}

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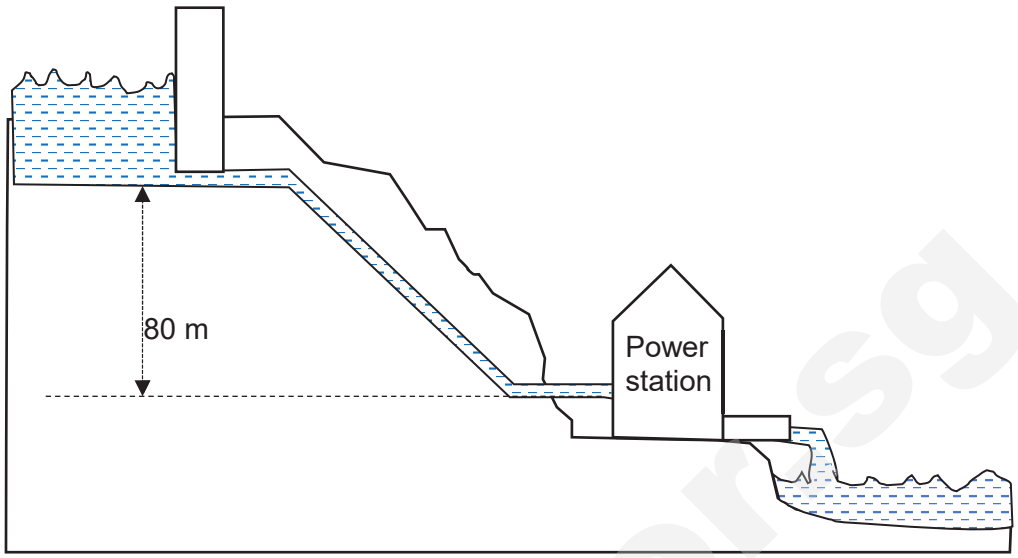
6 A hydroelectric power station is shown in the figure below.



Water is supplied from a reservoir which is 80 m above the power station. The water passes through its turbines at a rate of 6.0 m^3 s^{-1}.

Assume that the density of water is 1000 kg m^{-3}.

If the efficiency of the power station is 60%, the electrical power output is

A 0.29 MW **B** 1.9 MW **C** 2.8 MW **D** 4.7 MW

7 The engine of a boat delivers 30.0 kW to the propeller while the boat is moving at a constant speed of 15.0 m s^{-1}. The total drag on the boat is proportional to the square of the speed of the boat. If the boat is being towed at 5.0 m s^{-1} after its engine has broken down, the average tension in the towline will be

A 44.4 N **B** 220 N **C** 2000 N **D** 3330 N

8 A light string can bear up to 3.7 kg of mass. A stone of mass 500 g is tied at its end and revolved in vertical circular path of radius 4.00 m. Taking g = 10 m s^{-2}, the maximum angular velocity of the stone is

A 3.0 rad s^{-1} **B** 4.0 rad s^{-1} **C** 5.0 rad s^{-1} **D** 6.0 rad s^{-1}

9 Given that the mass of Earth is M_E, the radius of Earth is R_E, the mass of Mars is M_M and the radius of Mars is R_M, the ratio of the escape speed on the surface of the Earth to the escape speed on the surface of Mars is

A $\sqrt{\frac{M_E}{M_M}\frac{R_E}{R_M}}$ **B** $\sqrt{\frac{M_E}{M_M}\frac{R_M}{R_E}}$ **C** $\sqrt{\frac{M_M}{M_E}\frac{R_E}{R_M}}$ **D** $\sqrt{\frac{M_M}{M_E}\frac{R_M}{R_E}}$

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10 The radius of planet X is twice the radius of planet Y and both planets have the same density. The ratio of the acceleration due to gravity at the surface of X to that at the surface of Y is

A 1 : 4 **B** 1 : 2 **C** 2 : 1 **D** 4 : 1

11 A 2.0 kg chunk of ice at -20 °C is placed in 4.0 kg of water at an initial temperature. Assuming that there is no heat loss to the surrounding, what is the initial temperature of the water that will allow all the ice to just melt?

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
Specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
Specific latent heat of fusion = 3.35×10^5 J kg^{-1}

A 20 °C **B** 40 °C **C** 45 °C **D** 90 °C

12 The density of a sample of helium gas at the pressure of 100 kPa is 0.178 kg m^{-3}. The root-mean-square speed of the helium molecules is

A 41 m s^{-1} **B** 1300 m s^{-1} **C** 561 km s^{-1} **D** 1685 km s^{-1}

13 A mole of a monatomic ideal gas is contained in a cylinder with a movable piston. The temperature of the gas is 200 K and the volume of the gas is 25 x 10^{-3} m^3.

The gas now expands at constant pressure such that the volume of the cylinder increases by 75 x 10^{-3} m^3. The change in internal energy of the gas is

A 7500 J **B** -7500 J **C** 10000 J **D** -10000 J

14 The first law of thermodynamics may be expressed as

$$\Delta U = q + w$$

where ΔU is the increase in internal energy of the system,
q is the thermal energy supplied to the system,
w is the work done on the system.

Some liquid at its freezing point contracts as it turns to a solid.
What are the changes in ΔU, q and w as the liquid freezes?

	ΔU	q	w
A	negative	negative	positive
B	negative	zero	positive
C	positive	zero	negative
D	zero	negative	positive

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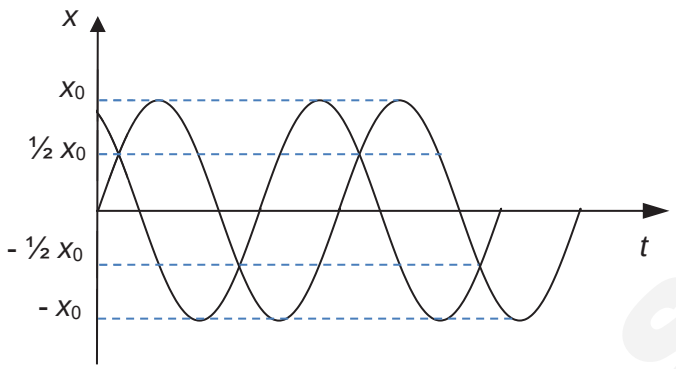
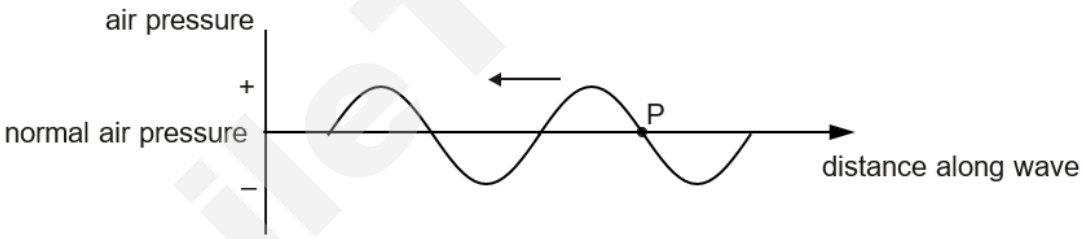
15 Two identical vertical spring mass systems hung at the same height execute simple harmonic motion of the same amplitude and frequency. The graph below shows the variation of the displacements of the masses with time. The masses pass one another at half the amplitude when they are going in opposite directions.



The phase difference between them is

A 90° **B** 120° **C** 135° **D** 150°

16 The graph below shows the variation of air pressure with distance along a wave at one given time. The arrow indicates the direction of travel of the wave.



The air pressure at point P is

A increasing

B decreasing

C constant

D zero

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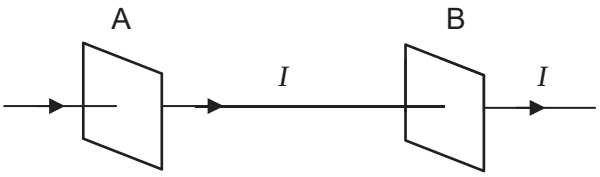
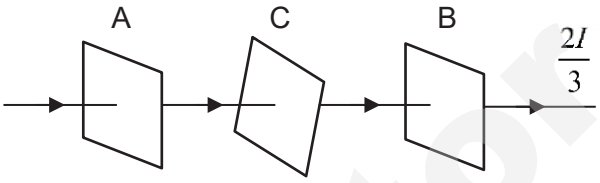
17 When a narrow beam of plane-polarised light passes through an ideal polariser A, the light intensity is observed to be I. When an identical polariser B is placed behind A, it is observed that the light intensity beyond B is still I.



A third identical polariser C is now inserted between A and B, causing the light intensity emerging from B to become $\frac{2I}{3}$.



What is the angle between the axes of polarisation of the polarisers A and C?

A 25.4º **B** 35.3º **C** 48.2º **D** 55.6º

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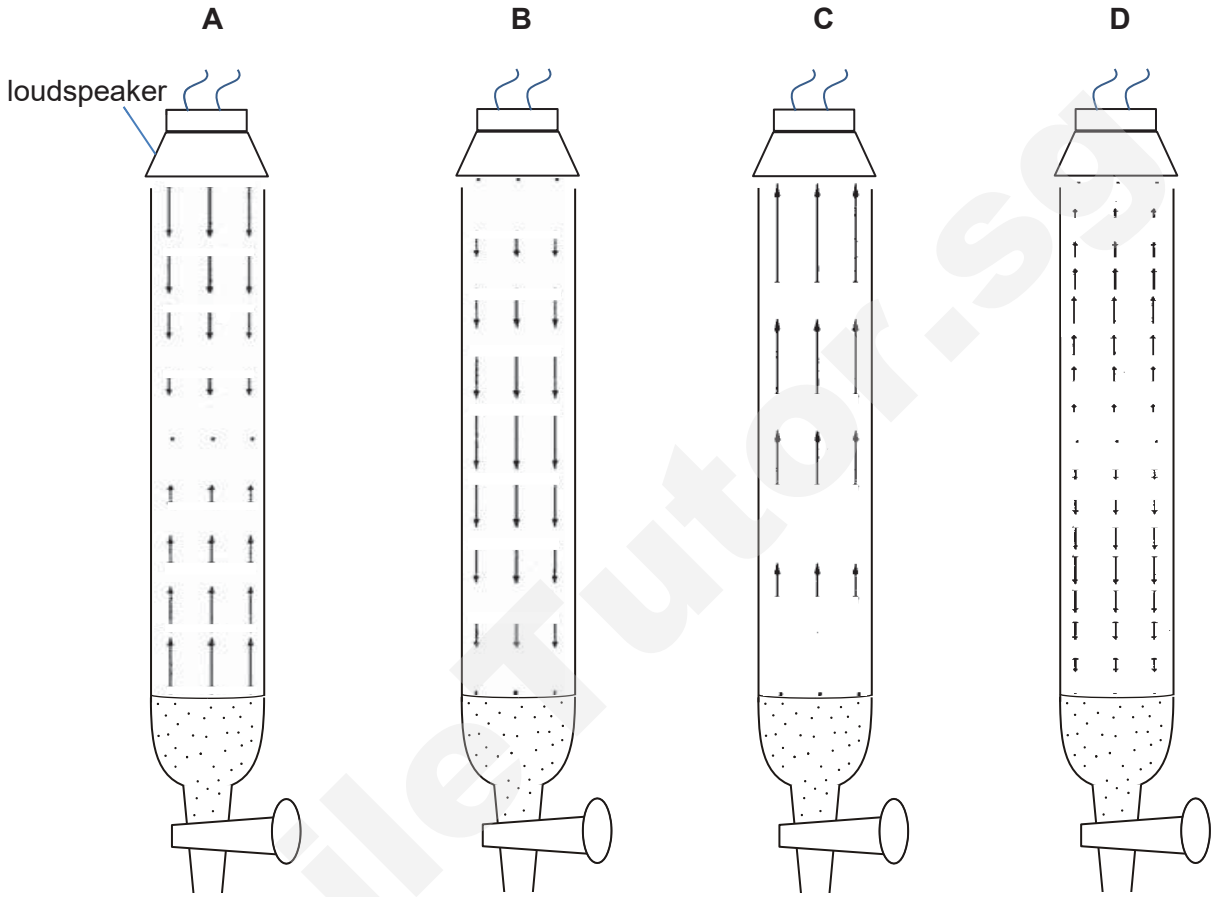
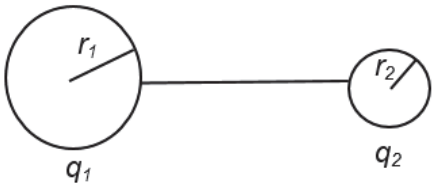
18 A loudspeaker generating a sound of a fixed frequency is held above the top of a burette filled with water. The water gradually runs out of the burette until a maximum loudness of the sound is heard.

Which of the following best shows a possible standing wave pattern set up by air molecules in the burette at this position?



19 Two spherical conductors of radii r_1 and r_2 are separated by a distance much greater than the radius of either sphere. The spheres are connected by a conducting wire as shown below. The charges on the spheres in equilibrium are q_1 and q_2 respectively. Find the ratio of the electric field at the surface of sphere 1 to the electric field at the surface of sphere 2.



A $\sqrt{\frac{r_2}{r_1}}$ **B** $\frac{r_2}{r_1}$ **C** $\frac{r_2^2}{r_1^2}$ **D** 1

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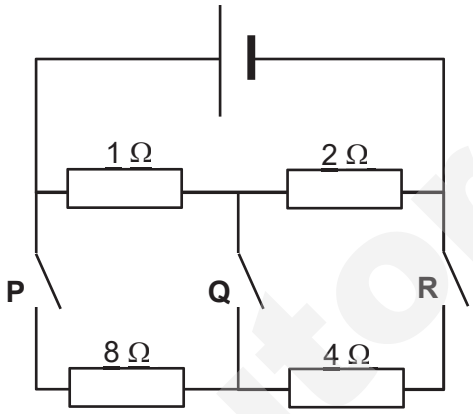
20 A copper wire of length l and diameter d has potential difference V applied at its two ends. The drift velocity of the electrons is v_d. If the diameter of copper wire is changed to $\frac{d}{3}$, the drift velocity becomes

A $9\,v_d$ **B** $v_d / 9$ **C** $v_d / 3$ **D** v_d

21 The figure below shows the arrangement of four resistors, each with a different resistance.



Which of the following switch settings will produce the greatest current in the circuit?

	P	Q	R
A	Open	Open	Open
B	Open	Closed	Closed
C	Closed	Open	Closed
D	Closed	Closed	Closed

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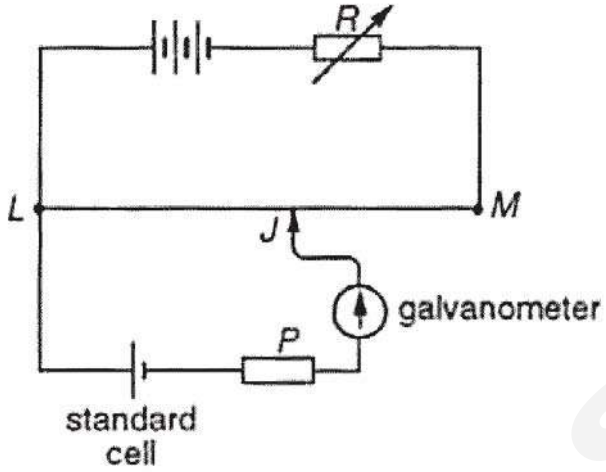
22 A potentiometer is to be calibrated with a standard cell using the circuit as shown.



The balance point is found to be near *L*. To reduce the percentage uncertainty, the balance point should be nearer *M*. This may be achieved by

A replacing the galvanometer with one of lower resistance.

B replacing the potentiometer wire with one of higher resistance per unit length.

C increasing the resistance *R*.

D removing the resistor *P*.

23 Two very long, straight, parallel wires carry equal steady current I in opposite directions. The distance between the wires is *d*. At a certain instant of time, a point charge *q* is at a point equidistant from the two wires, in the plane of the wires. Its instantaneous velocity *v* is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is

A 0 N **B** $\frac{\mu_0 Iqv}{2\pi d}$ **C** $\frac{\mu_0 Iqv}{\pi d}$ **D** $\frac{2\mu_0 Iqv}{\pi d}$

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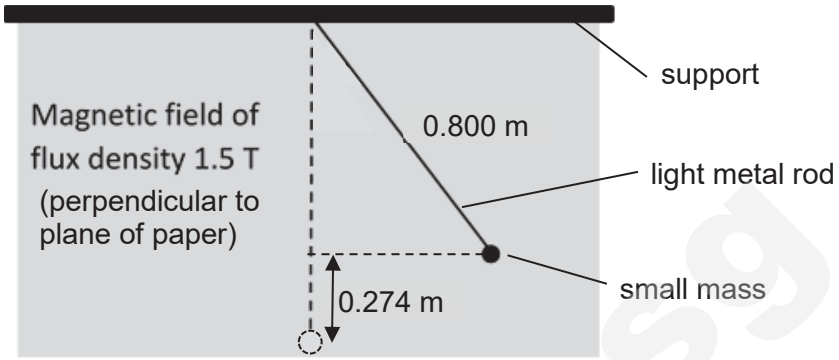
24 A small mass hangs at the end of a thin light metal rod of length 0.800 m hinged at one end to a support. The mass is brought to a height of 0.274 m. It is then released from rest to oscillate in a uniform magnetic field of magnetic flux density 1.5 T as shown.



Which of the following gives the average speed of the rod and the instantaneous e.m.f. induced in the rod at its lowest point of oscillation?

	average speed of the rod / m s^{-1}	induced e.m.f. / V
A	2.32	1.4
B	2.32	2.8
C	1.16	1.4
D	1.16	2.8

25 Fig. 25 (a) shows two concentric circular conductors lying in the same plane. The current in the outer loop is clockwise and changes with time as shown in Fig. 25 (b).

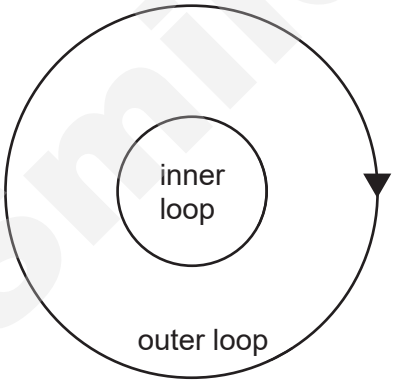


Fig. 25 (a)

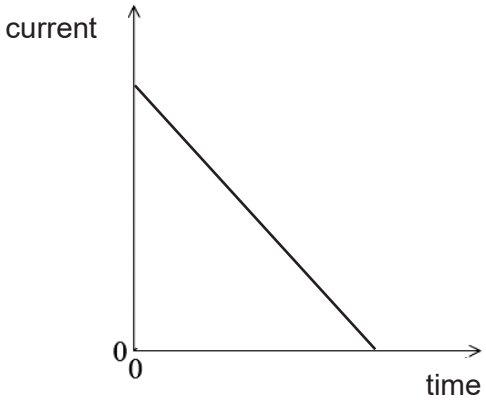


Fig. 25 (b)

The induced current in the inner loop is

A constant in the clockwise direction.
B variable in the clockwise direction.
C constant in the anticlockwise direction.
D variable in the anticlockwise direction.

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26 Fig. 26 (a) and (b) shows two separate types of alternating potential difference with the same peak voltage (V_p) applied across a load resistor R.

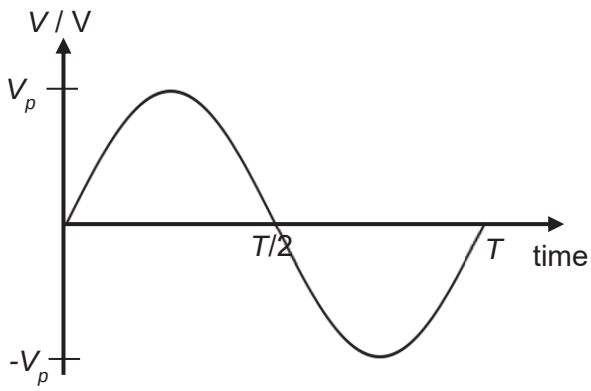

Fig. 26 (a)

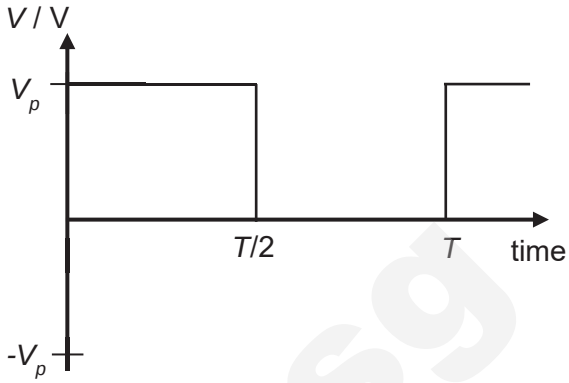

Fig. 26 (b)

What is the ratio $\frac{\text{root-mean-square potential difference for (a)}}{\text{root-mean-square potential difference for (b)}}$?

A 0.5 **B** 0.7 **C** 1 **D** 1.4

27 The continuous optical spectrum of light from the Sun, observed from the Earth is crossed by dark lines at particular wavelengths. The photosphere is the outer layer of gas around the Sun's core. Which one of the following statements correctly accounts for these dark lines?

A The elements that exist in the photosphere which are hotter than the Sun's inner regions, absorb the photons emitted from the Sun.

B The elements that exist in the solar interior absorb the photons emitted from the Sun.

C The elements found in the Earth's atmosphere absorb the photons emitted from the Sun.

D The elements that exist in the cooler photosphere absorb the photons emitted from the Sun.

28 Electrons in a cathode ray tube are accelerated from rest through a potential difference V. What percentage change in the de Broglie wavelength associated with these electrons will occur if the potential difference through which these electrons are accelerated is doubled?

A 29% decrease
B 50% decrease
C No change
D 29% increase

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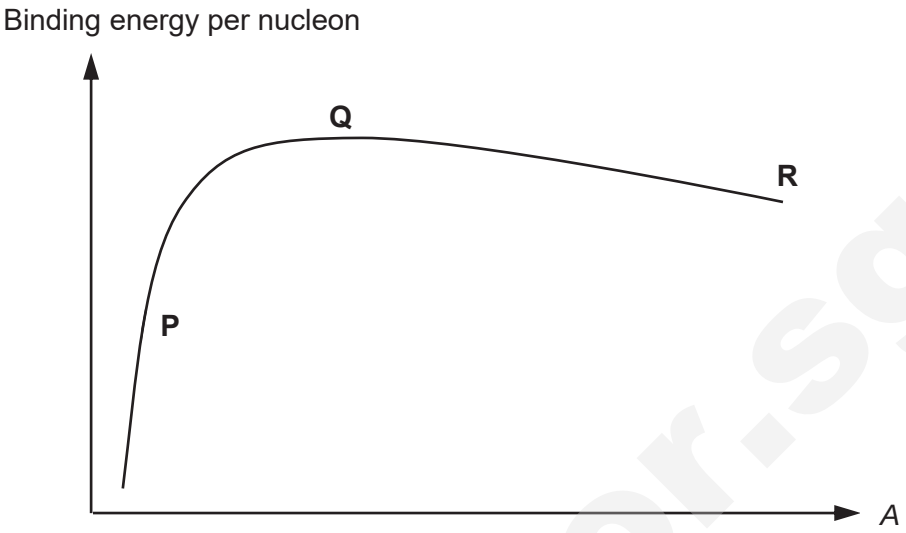
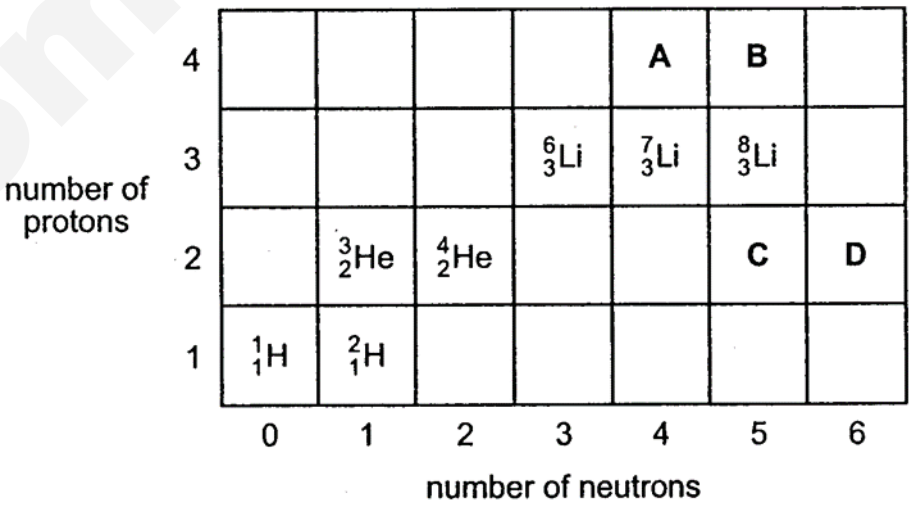
29 The graph below shows how the binding energy per nucleon of a nucleus varies with nucleon number *A*.



Which one of the following statements is **not** true?

A Nuclear fusion reactions bring nuclei closer to region Q.
B Nuclei in region Q are more stable than nuclei in region R.
C Energy is released in nuclear fission reactions from nuclei in region P.
D The binding energy per nucleon increases most significantly at lower nucleon numbers.

30 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each. A nucleus of the nuclide $^{8}_{3}\text{Li}$ decays by emitting a β particle. What is the resulting nuclide?



End of Paper

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JC2 Preliminary Examinations
Higher 2

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PHYSICS

9749/02

Paper 2 Structured Questions

13 September 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paperclips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Paper 1		**30**
Paper 2		
1		**10**
2		**11**
3		**10**
4		**10**
5		**10**
6		**10**
7		**19**
Deductions		
Total		**80**

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Data

speed of light in free space,
$c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space,
$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge,
$e = 1.60 \times 10^{-19}$ C

the Planck constant,
$h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant,
$u = 1.66 \times 10^{-27}$ kg

rest mass of electron,
$m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton,
$m_p = 1.67 \times 10^{-27}$ kg

molar gas constant,
$R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant,
$N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant,
$k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant,
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

acceleration of free fall,
$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/ by a gas, $W = p\,\Delta V$

hydrostatic pressure $p = \rho g h$

gravitational potential, $\phi = -\frac{Gm}{r}$

temperature T/K = T/ °C + 273.15

pressure of an ideal gas $P = \frac{1}{3}\frac{Nm}{V} < c^2 >$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm \omega \sqrt{(x_o^2 - x^2)}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire
$B = \frac{\mu_o I}{2\pi d}$

magnetic flux density due to a flat circular coil
$B = \frac{\mu_o N I}{2r}$

magnetic flux density due to a long solenoid
$B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 a) Explain two conditions required for a body to be in a state of equilibrium.

1.....

.....

2.....

.....[2]

b) Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.

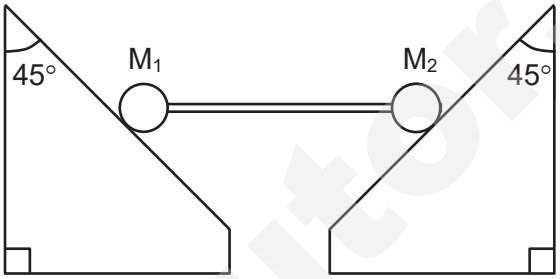

Fig. 1.1

(i) The system (2 spheres and the bar as one rigid body) is in a state of equilibrium when the bar is horizontal. Draw and label clearly the forces acting on the system in Fig 1.1.

[2]

(ii) Calculate the contact force that the incline exerts on M_1.

force = ... N [2]

(c) M_2 is now replaced by M_3, a sphere with mass of 4 kg.

(i) Explain why the contact forces that the inclines exert on M_1 and M_3 must be equal in magnitude, for the system to be in a state of equilibrium.

.....

.....

.....[1]

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(ii) Explain why, for the system to be in a state of equilibrium, the bar cannot be horizontal.

……

……

……

……[2]

(iii) Hence, sketch in Fig. 1.2 how the system should be placed on the inclines so that the system is in a state of equilibrium. (Label M_1 and M_3)

[1]

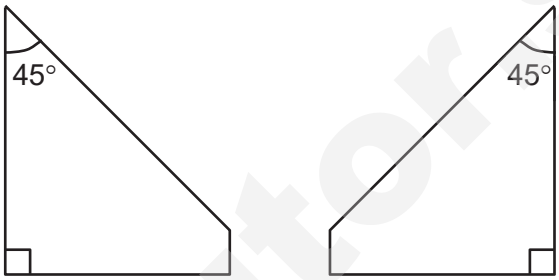

Fig. 1.2

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2 **(a)** Define gravitational field strength.

……

……

…….. [1]

(b) Consider a satellite of mass *m,* orbiting the Earth of mass M_E, in a circular path of radius *r*, with an orbital period of *T*.

(i) Write down an expression for the acceleration of the satellite in terms of M_E, *r* and *G* (the gravitational constant).

[1]

(ii) Show that T^2 is proportional to r^3, and obtain an expression for the constant of proportionality.

constant of proportionality = …….. [3]

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Raduga 5 is a Russian-owned geostationary satellite launched in April 1979.

(iii) Determine the angular velocity of Raduga 5.

angular velocity = ……..rad s^{-1} [1]

(iv) Given that the radius of the Earth $= 6.4 \times 10^6$ m and the mass of the Earth $= 6.0 \times 10^{24}$ kg, determine the altitude that Raduga 5 maintains above the surface of the Earth.

altitude = ……..m [3]

(v) Suggest, with a reason, a possible use of the Raduga 5 geostationary satellite.

……

……

……

……[2]

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3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

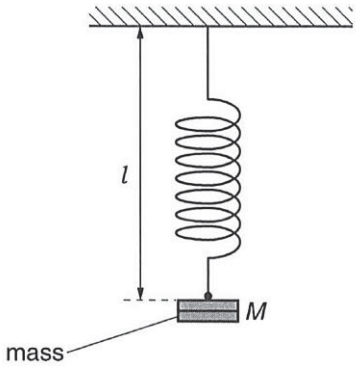

Fig. 3.1

This arrangement is used to determine the length l of the spring when mass M is attached to the spring. The procedure is repeated for different values of M. The variation of mass M with length l is shown in Fig. 3.2.

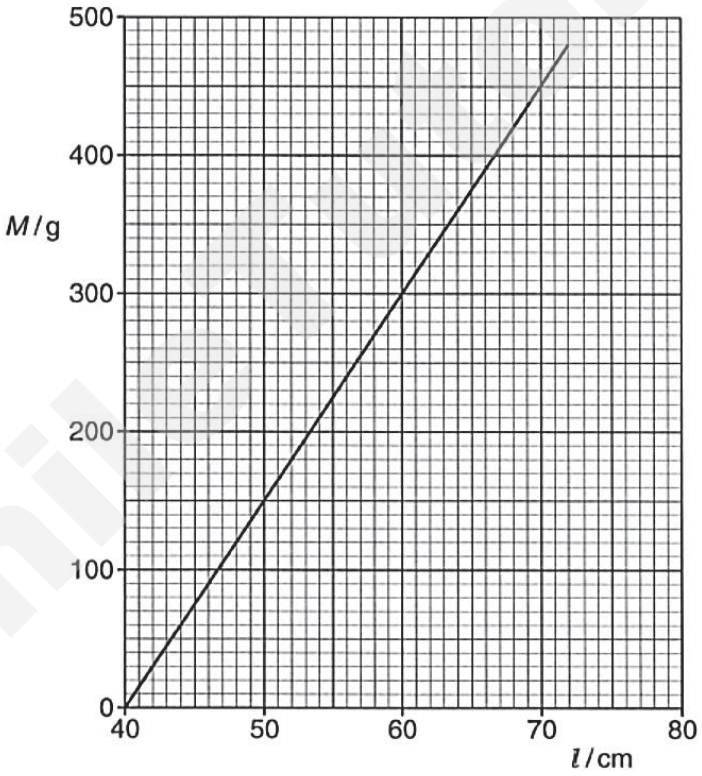

Fig. 3.2

(a) Show that the spring constant k of the spring is 14.7 N m^{-1}. [2]

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(b) A mass of 450 g is attached to the spring and is held at rest with length l of 50.0 cm. The mass is then released and the mass oscillates freely. The angular frequency of the spring-mass system is given by the formula

$$\omega = \sqrt{\frac{k}{m}}$$

(i) Calculate the frequency of the system.

frequency = ……..……..……..Hz [2]

(ii) Calculate the speed of the mass during its oscillation when the spring is extended to a length l of 80.0 cm.

speed = ……..……..…….. m s^{-1} [4]

(c) The spring is assumed to be light. In practice, the spring will have some mass. Assuming that the spring constant k is unchanged, suggest and explain the effect on the frequency of oscillation of having a spring with mass.

……

……

……

……..[2]

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4 **(a)** State what is meant by *diffraction* and *destructive interference*.

diffraction:……..

……

destructive interference: ……

……

……

……

[3]

(b) In Fig. 4.1, a red laser with a frequency of 4.69×10^{14} Hz is incident on a diffraction grating of 3000 lines per cm. The screen 2.30 m from the grating captures the whole interference pattern.

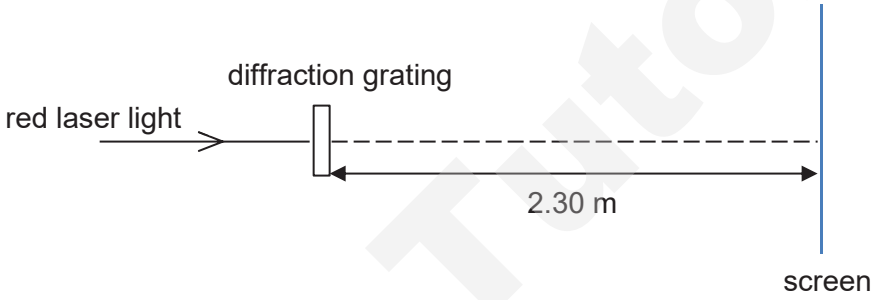

Fig. 4.1

(i) Determine the possible number of intensity maxima on the screen.

possible number of intensity maxima = …….. [3]

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(ii) Determine the distance of the furthest maximum away from the central maximum on the screen.

distance = ……..…….…….. m [2]

(c) The red laser is replaced with a green laser. How would this affect the pattern on the screen? Explain your answer.

……

……

……[1]

(d) Suggest why it is better to use a diffraction grating than a double slit to determine the wavelength of the laser.

……

……

……[1]

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5 In order to investigate the photoelectric effect, a student varied the wavelength of the radiation incident on the metal surface. For each value of wavelength λ, the stopping voltage V_s required just to prevent electrons from reaching the electrode was measured. Two such data are shown in Fig. 5.1.

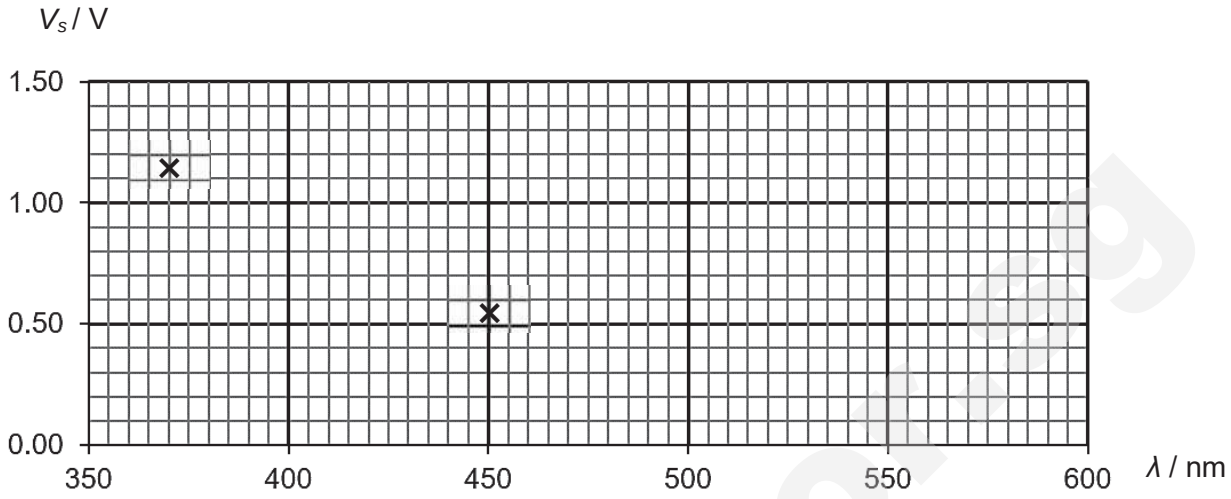

Fig. 5.1

(a) What is the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 370 nm?

maximum kinetic energy = …….…….…….. J [2]

(b) Calculate the energy of a photon of wavelength 370 nm.

energy of photon = …….…….…….. J [2]

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(c) Using your answers to **(a)** and **(b)**, show that the threshold wavelength is 560 nm.

[2]

(d) Without further calculations, sketch in Fig. 5.1 the graph that the student should obtain at the end of the experiment.

[2]

(e) The student decided to repeat the experiment by doubling the intensity of the radiation incident on the metal surface. State and explain whether this change would affect the results obtained in Fig. 5.1.

……

……

……

……[2]

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6 **(a)** Isotope X undergoes radioactive decay to form isotope Y. The half-life of isotope X is 2.0×10^5 years. The activity of a pure sample of isotope X extracted from an ore is measured to be 1.1×10^7 Bq.

(i) State what is meant by isotopes.

……

……[1]

(ii) Explain why the measured activity of the sample X is relatively constant.

……

……[1]

(iii) It is discovered that isotope Y undergoes radioactive decay to form isotope Z. The half-life of isotope Y is 1.5 hours.

1. Calculate the decay constant of Y.

decay constant of Y = …… s^{-1} [1]

2. The number of isotope Y in the sample is found to be constant. Explain how this is possible.

……

……

……[1]

3. Hence, determine this amount of Y.

amount of Y = …… atoms [2]

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(b) Th-232 decays by alpha-emission with a decay constant of 1.57×10^{-18} s^{-1}. This is the beginning of a decay chain which eventually ends in Pb-208. A sample of rock is found to contain both Th-232 and Pb-208 in the ratio of 5:1.

(i) When the rock was formed, there was no Pb-208 present in the sample. Estimate the age of the rock.

age of rock = ……..…….…….. years [2]

(ii) State the assumption made in **(b)(i)** regarding the intermediate product nuclei.

……..……

……..……

……..…[1]

(iii) State with a reason, whether your answer in **(b)(i)** is an overestimate or an underestimate of the age of the rock if the assumption in **(b)(ii)** is not valid.

……..……

……..……

……..……

……..…[1]

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7 The article below is freely adapted from "What if I Double It?" by Thomas Humphrey.

Read the article and then answer the questions that follow.

What if I Double It?

Suppose you are responsible for cooking a turkey and have access to a large range of cookbooks. You have a 9.0 kg turkey but the first cookbook you consult only tells you how long it takes to cook a 4.5 kg turkey. Since the 9.0 kg turkey is twice the size of a 4.5 kg bird, at first the answer might seem obvious. Simply double the cooking time suggested for a 4.5 kg turkey. But is this really the right thing to do?

A second cookbook suggests that when you double the weight of a turkey, you don't have to double the cooking time. It indicates a cooking time of 4.0 hours for the small bird and 6.5 hours for the larger bird. So even though the 9.0 kg turkey is twice the weight of the 4.5 kg turkey, you only have to cook it about 1.6 times as long. Why would that be?

A more detailed analysis reveals that a turkey has more features than just its mass. When the mass is doubled other features such as width, surface area and volume are also scaled up. The turkey also has a density, a thermal conductivity (how well it transfers the oven's heat to its interior), and a specific heat capacity (how much heat it needs to climb one degree Celsius in temperature). How do some or all of these factors change in going from a 4.5 kg to a 9.0 kg turkey?

Let's imagine that our turkey is shaped like a cube. This will make it easier to see how the various factors change. Take a look at the cubical turkeys in Fig. 7.1.



Fig.7.1

If you count the number of small cubes in the 4.5 kg turkey, you will find that there are $4 \times 4 \times 4$,
or 64 cubes. The number of cubes in the 9.0 kg turkey is $5 \times 5 \times 5$, or 125 cubes. That's not exactly double, but it's pretty close. So now we know that the 9.0 kg turkey is about twice the volume of the 4.5 kg turkey (that is, it contains twice as many little cubes), and therefore it weighs about twice as much.

So when you double the size of the turkey, what happens to its width and surface area? Do they double too? If you look at the cubical turkeys above, you can see that the widths of the two turkeys are 4 and 5 blocks respectively. So the bigger turkey is about 25% wider than the smaller one. The width did not double.

If we look at surface area, the smaller turkey has 6 sides × 16 blocks per side, or 96 blocks. The surface area of the big turkey has 6 sides × 25 blocks per side, or 150 blocks. That means that the big turkey has about 50 percent more blocks on its surface than the small turkey. The surface area did not double either.

More precisely, on a real turkey, the width and all other linear dimensions increase by a factor of 1.26 and the surface area by a factor 1.59. Now let's analyse how this information allows us to make predictions as to a turkey's cooking times.

The 9.0 kg turkey, because it has doubled in volume, has twice as much stuff in it to be heated up, so we need to put in twice as much heat. How does this heat get into it? It is transferred across the surface of the turkey, traveling from the surface to the core of the bird. The bigger turkey has more surface area. That should speed up the transfer of heat, but the

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heat has to travel a longer way to the centre. That will slow things down. The net result is that it doesn't take twice as long to cook a twice-as heavy turkey. The physics fits with the information in the cookbook!

If we put the three factors together, the cooking time increases by a factor of 1.59 to 6.4 hours. Our cook book says to increase the time to 6.5 hours, or by a factor of 1.62. (6.5 hrs ÷ 4 hrs = 1.62). That's pretty close!

So now we know how to cook a turkey. We have discovered that the seemingly innocuous question, " What happens if you double it?" has turned out to be rather more complex than we had initially thought. We must be very specific about which feature of the turkey we are doubling because we don't seem to be able to double everything at once!

(a) An important factor is missing from the explanation of specific heat capacity. Modify the statement to make it more accurate (lines 13-14)

……

……[1]

(b) **(i)** Show how the factors 1.26 and 1.59 mentioned in line 32 can be proven mathematically.

[2]

(ii) The smaller (4.5 kg) turkey has a width of 22 cm. Calculate the width of the larger (9.0 kg) turkey (lines 31-33)

width = …….…….…….. cm [1]

(iii) The larger turkey (9.0 kg) has a surface area of 0.46 m^2. Calculate the surface area of the smaller (4.5 kg) turkey (lines 31-33)

surface area = …….…….…….. m^2 [1]

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(c) The turkeys are considered to be cooked when their average temperature has risen 90 ºC.

(i) How much thermal energy does this require for the 9.0 kg turkey? (Specific heat capacity of turkey = 3200 J kg^{-1} $°C^{-1}$).

energy = …….…….…….. J [2]

(ii) The electrical power supplied to the cooking oven was 2200 W. If all this energy was transferred as thermal energy to the turkey, how long should the 9.0 kg turkey have taken to cook?

time = …….…….…….. s [1]

(iii) Suggest two reasons why there is such a large difference between the answer to **(c)(ii)** and the time given in the passage?

……

……

……

……

……

……[2]

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(d) Show mathematically how the three factors discussed in lines 34-40 when combined, lead to the conclusion that the 9.0 kg turkey requires a cooking time 1.59 times longer than for a 4.5 kg turkey.

[2]

(e) The rate of heat transfer through a cylindrical object is given by the equation

$$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta \theta}{\Delta x}$$

where
k is a constant which is the thermal conductivity of the object,
A is the cross-sectional area of the cylinder,
Δx is the length of the cylinder, and
$\Delta \theta$ is the temperature difference across the length of the cylinder.

This equation can be used to provide a crude estimate of the rate of heat conduction from the surface to the core of the turkey.

(i) You may assume that during the cooking of the turkey, the temperature difference ($\Delta \theta$) remains at a constant 140 ºC and that this temperature gradient occurs over **half the width of the turkey.** Estimate the rate of heat transfer for the 9.0 kg turkey (with the help of data from **(b)(ii)** and **(b)(iii)**).
(Thermal conductivity, k for the turkey = 0.60 in S.I. units)

rate of heat transfer = …….. W [3]

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(ii) Assuming that this rate of heat transfer to the turkey remains constant over the cooking time and using your result of **(c)(i)**, calculate the cooking time for the 9.0 kg turkey in hours.

time = ……..…….. hr [1]

(iii) Use the answer to **(e)(ii)** to calculate the cooking time for an 18.0 kg turkey.

time = ……..…….. hr [1]

(iv) What are the S.I. base units for the constant k?

S.I. base units = ……..…….. [2]

End of Paper

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HWA CHONG INSTITUTION
JC2 Preliminary Exam
Higher 2

CANDIDATE NAME		**CT GROUP**	**16S**
TUTOR NAME			

PHYSICS

9749/03

Paper 3 Longer Structured Questions

15 Sep 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		**10**
2		**10**
3		**10**
4		**10**
5		**9**
6		**11**
Section B (Answer **ONE** question only and circle below the question answered)		
7		**20**
8		**20**
Deductions		
Total		**80**

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Data

speed of light in free space,
$c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space,
$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge,
$e = 1.60 \times 10^{-19}$ C

the Planck constant,
$h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant,
$u = 1.66 \times 10^{-27}$ kg

rest mass of electron,
$m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton,
$m_p = 1.67 \times 10^{-27}$ kg

molar gas constant,
$R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant,
$N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant,
$k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant,
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

acceleration of free fall,
$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/ by a gas, $W = p\,\Delta V$

hydrostatic pressure $p = \rho g h$

gravitational potential, $\phi = -\frac{Gm}{r}$

temperature T/K = T/ °C + 273.15

pressure of an ideal gas $P = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm \omega \sqrt{(x_o^2 - x^2)}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire
$B = \frac{\mu_o I}{2\pi d}$

magnetic flux density due to a flat circular coil
$B = \frac{\mu_o N I}{2r}$

magnetic flux density due to a long solenoid
$B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in the spaces provided.

1 (a) (i) Define *acceleration*.

……

…… [1]

(ii) Use your definition in (a)(i) and the definition of average velocity to derive an expression for v in terms of u, a and s where v is the final velocity, u is the initial velocity, a the uniform acceleration, t the time interval and s the distance travelled.

[2]

(b) The graph of Fig 1.1 shows the variation with time of the velocity v of a ball of mass 320 g from the moment it is thrown with a velocity of 20 m s^{-1} vertically upwards to the moment it returns to the thrower's hand.

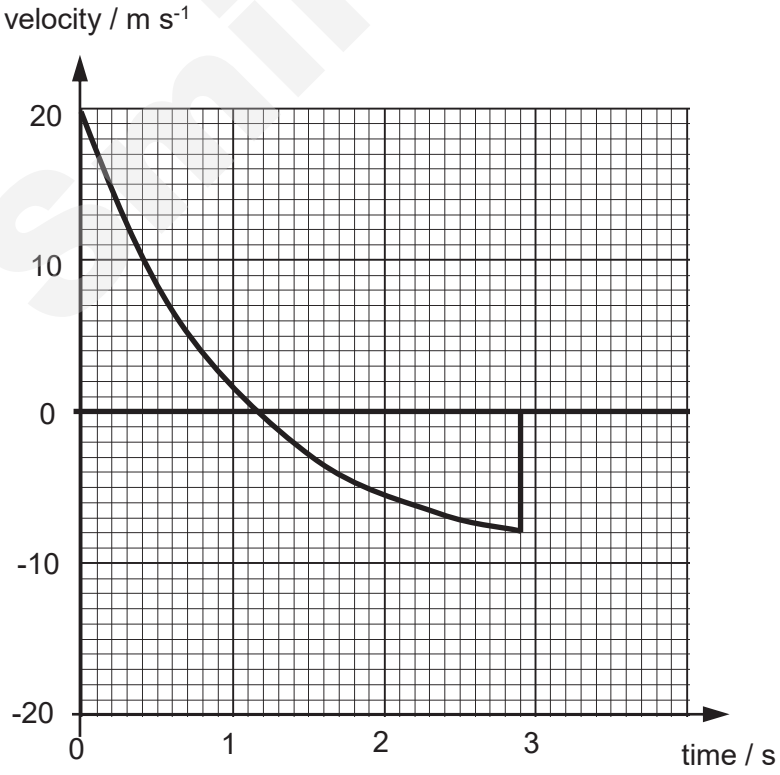

Fig. 1.1

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(b) **(i)** State the time at which the ball reaches its maximum height.

time = …… s [1]

(ii) Determine the acceleration of the ball 0.5 s after leaving the thrower's hand.

acceleration = …… m s^{-2} [2]

(iii) Based on your answer in (b)(ii), determine the magnitude of the drag force on the ball 0.5 s after leaving the thrower's hand.

drag force = …… N [2]

(iv) Explain why the time taken on the way up to maximum height is less than the time taken on the way down to the thrower's hand.

……

……

……

……

…… [2]

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2 A steel ball of mass m = 200 g is fixed, using glue, to one end P of a light rigid rod CP of negligible mass as shown in Fig. 2.1.

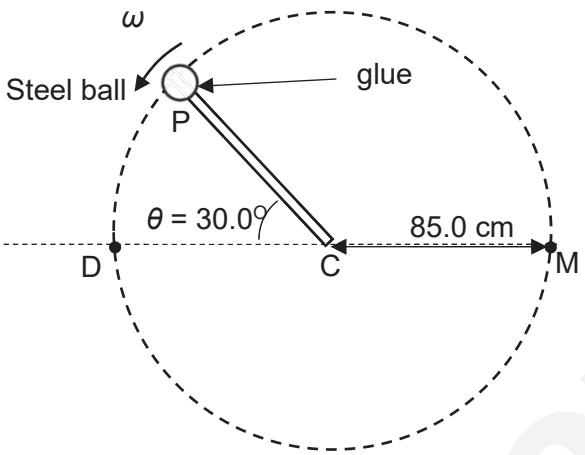

Fig. 2.1

The rod is rotated by an electric motor in a vertical plane about end C so that the ball moves in a vertical circle of radius 85.0 cm with constant angular velocity ω.

(a) (i) Determine the loss in the gravitational potential energy of the steel ball when it is being rotated from the position 30° above horizontal, P, to the horizontal position D.

loss in gravitational potential energy = …….. J [2]

(ii) Hence, explain whether the work done by the electric motor on the rod and the ball is positive or negative when the ball is moved from P to D.

……

……

…… [1]

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(iii) State the work done by the electric motor on the rod and the ball when the steel ball is being rotated from P to D.

work done by electric motor = …….. J [1]

(b) The angular speed of the rod and ball is gradually increased until the glue fixing the ball snaps. The glue snaps when the tension in it is 8.50 N.

(i) Mark with the letter S on the dotted circle in Fig. 2.1 the position of the ball where the glue is likely to snap. Sketch on Fig. 2.1 the subsequent path taken by the ball after the glue snaps. [2]

(ii) Calculate the angular speed of the ball when the glue holding the steel ball to the rod snaps.

angular speed of the ball = ……. rad s^{-1} [2]

(c) The steel ball is replaced with a hollow box containing a small steel cube. The hollow box is **permanently fixed** to the rigid rod. The small steel cube is free to move inside the box as shown in Fig 2.2. The mass of the small steel cube is 50 g.

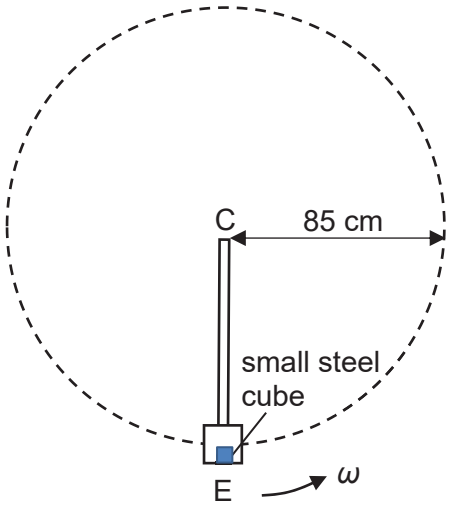

Fig 2.2

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Determine the minimum angular speed, ω_0, at which the steel cube remains in contact with the edge E of the box all the time.

ω_0 = ... rad s^{-1} [2]

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3 Fig. 3.1 shows a simple heat engine. A load on the platform is raised and thereby gained gravitational potential energy when gas inside the metal cylinder is heated by the heat reservoir. In this way, thermal energy is converted into mechanical energy.

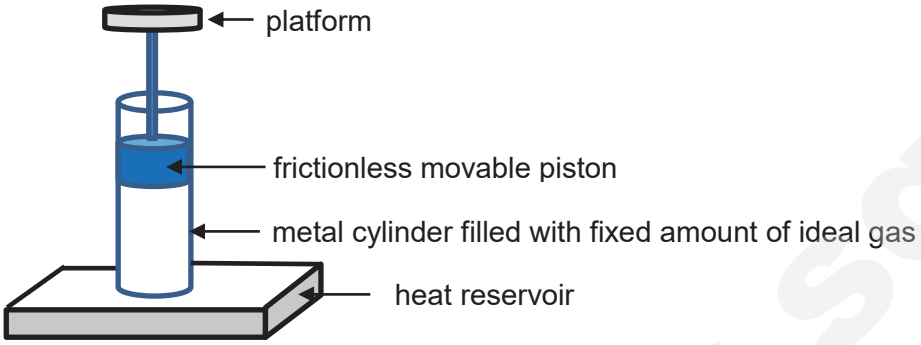

Fig. 3.1

In one cycle, the heat engine goes through the states $(A \rightarrow B \rightarrow C \rightarrow D \rightarrow A)$ as shown in Fig. 3.2.

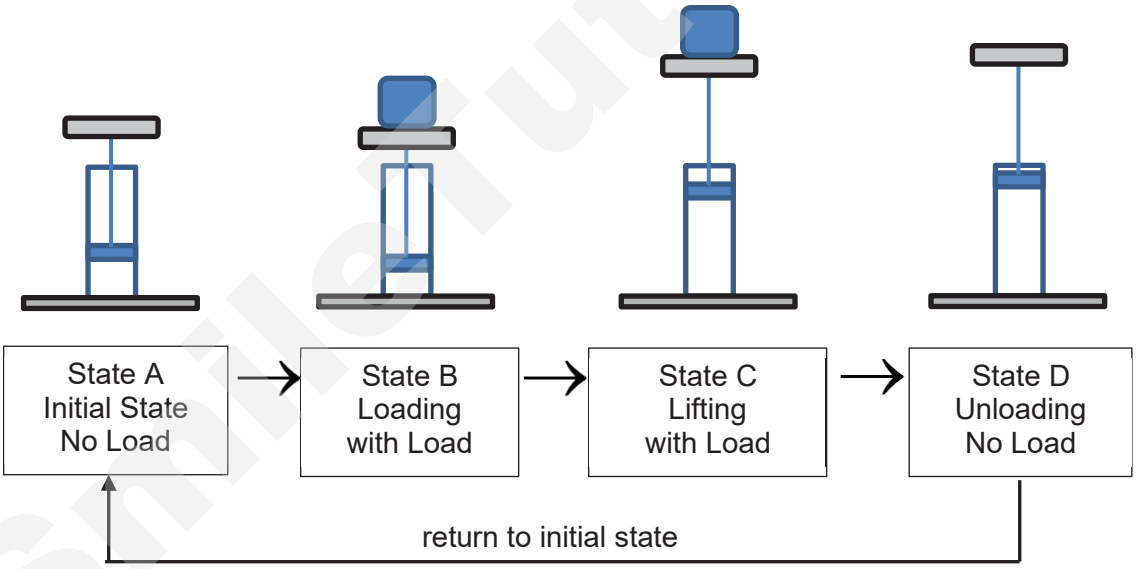

Fig. 3.2 one cycle of the heat engine

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(a) Table 3.1 shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B, C and D.

	Ideal Gas		
State	Pressure (kPa)	Volume (m^3)	Temperature (K)
A	102	1.000	292
B	103	0.990	292
C	103	1.197	353
D	102		353

Table 3.1

(i) Explain why the pressure for states A and D are the same.

……

……

……

…… [1]

(ii) Complete Table 3.1 by filling in the volume for state D.

[2]

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(b) The *P-V* graph (Fig. 3.3) below illustrates the cycle of changes of pressure, volume and temperature undergone by the fixed mass of ideal gas inside the metal cylinder from state A to state B to state C.

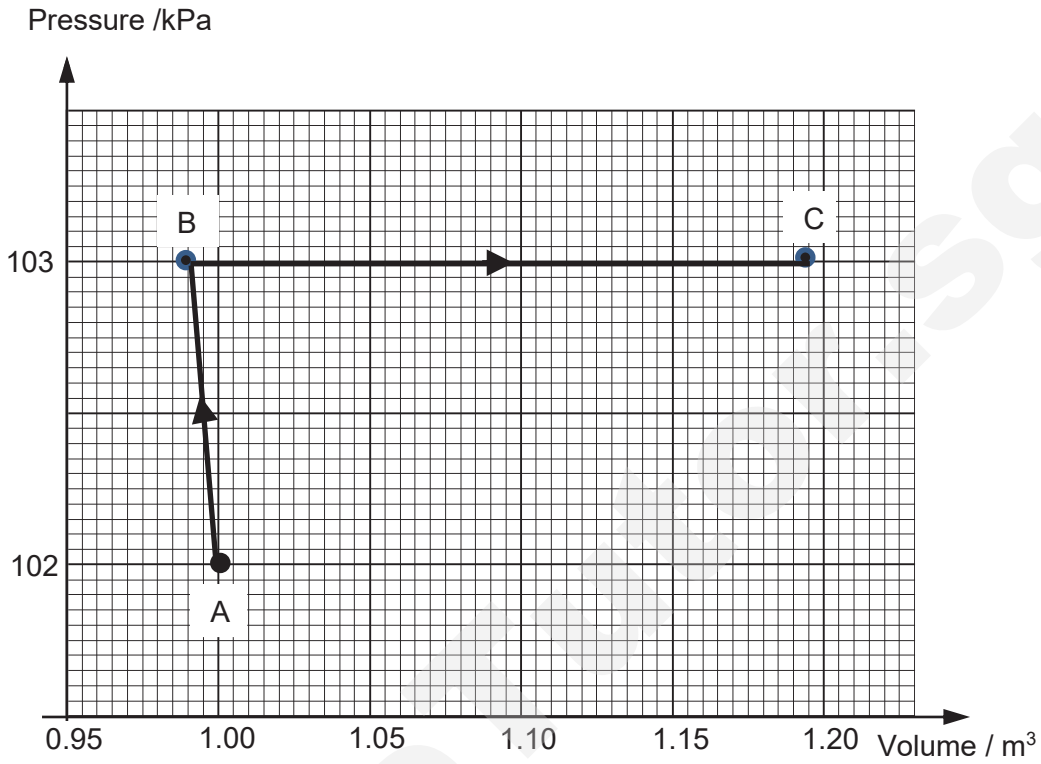

Fig. 3.3

(i) Mark and label state D on Fig. 3.3 and draw the process lines joining state C to state D to state A. [1]

(ii) Hence, using Fig. 3.3, estimate the work done by the ideal gas in one cycle.

work done = …….. J [2]

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(c) By considering the kinetic energy of the ideal gas in the metal cylinder, determine the amount of thermal energy, Q absorbed by the gas from the heat reservoir as it goes from state B to C.

Q = …….. J [4]

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4 **(a)** Define *electric field strength*.

……

……..... [1]

(b) A small charged sphere of mass 250 g and charge −12 mC is suspended between two parallel plates with a potential difference set up between them. The angle of inclination to the vertical is 40°, as shown in Fig. 4.1.

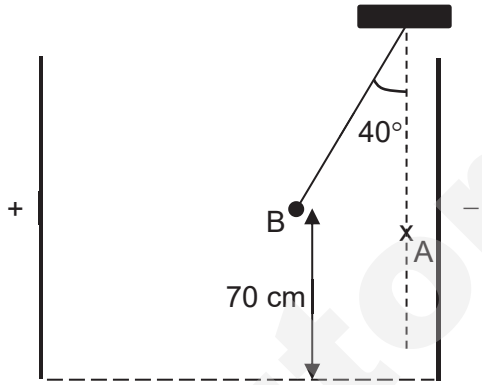

Fig. 4.1

(i) Show that the tension in the string is 3.2 N.

[1]

(ii) 1. Calculate the electric field strength between the plates.

electric field strength = …… V m^{-1} [2]

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2. Given further that the length of the string is 0.70 m, calculate the electric potential difference the sphere moves through between positions A and B.

potential difference = …… V [2]

(iii) The string is cut at the position shown on Fig. 4.1. Draw on Fig. 4.1 the path the sphere takes until the point it exits the plates. [1]

(iv) Use energy considerations to calculate the gain in kinetic energy of the sphere when it exits the electric field.

gain in kinetic energy = …… J [3]

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5 The variation with potential difference (p.d.) V of current I for a semiconductor diode is shown in Fig. 5.1.

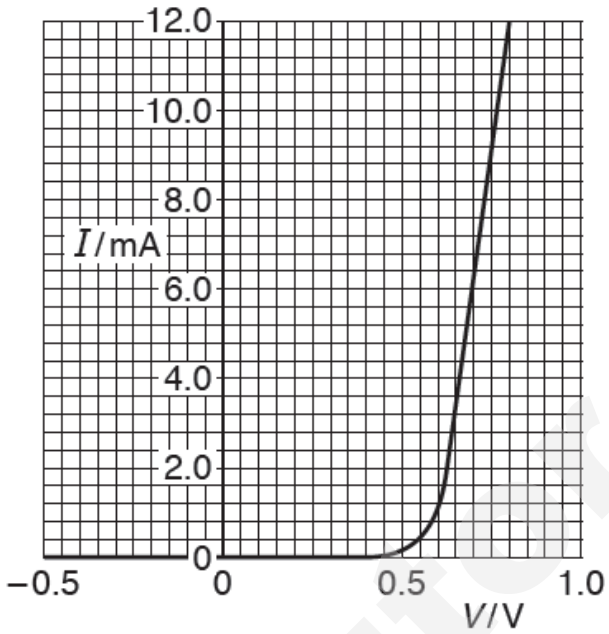

Fig. 5.1

(a) With reference to Fig. 5.1, describe the variation of the resistance of the diode between $V = -0.5$ V and $V = 0.8$ V.

.....

.....

.....

..... [2]

(b) On Fig. 5.2, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required. [2]

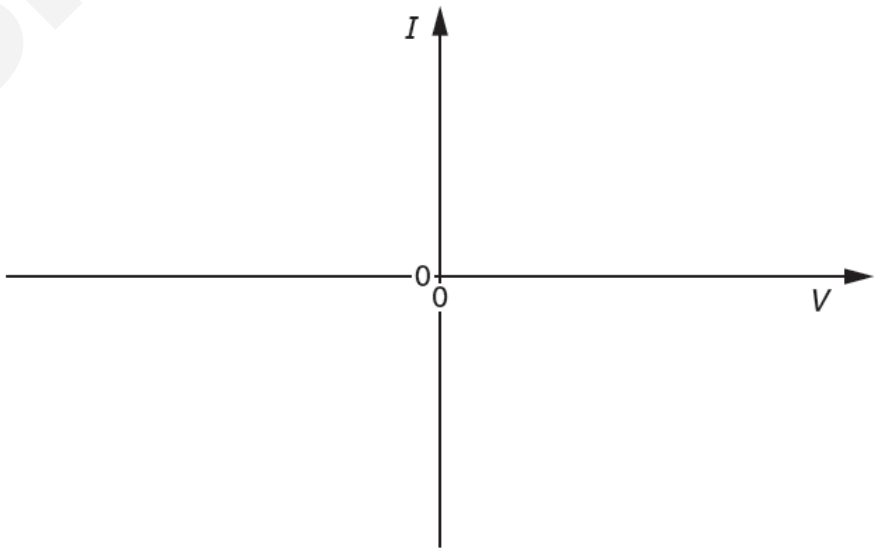

Fig 5.2

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(c) **(i)** A filament lamp has a power rating of 36 W when the p.d. across it is 12 V. Calculate the resistance of the lamp when the p.d. across it is 12 V.

resistance = ……Ω [1]

(ii) The filament lamp in (c)(i) is connected in series to a switch and a power supply of electromotive force (e.m.f.) 12 V and internal resistance 0.50 Ω as shown in Fig. 5.3.

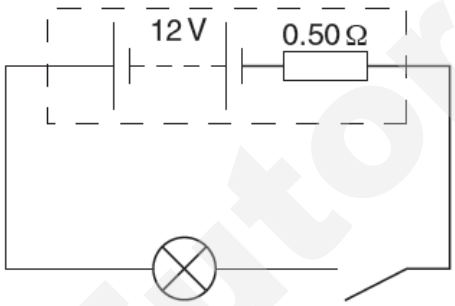

Fig. 5.3

The switch is closed and the current in the lamp is 2.8 A. Calculate the resistance of the lamp.

resistance = ……Ω [2]

(iii) Hence, determine the percentage of the power supplied by the cell dissipated across the filament lamp in the circuit in Fig. 5.3.

percentage of power supplied = …… [2]

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6 (a) State *Faraday's Law of Electromagnetic Induction*.

……

……

……

…… [2]

(b) An anemometer is a gauge for measuring the velocity of the wind. It is made by attaching cups to each end of a metal rod 50.0 cm long fixed rigidly to a central vertical column which can rotate freely. A square vertical coil of side 10.0 cm is attached to the column, as shown in Fig. 6.1, and the wind speed is measured by finding the e.m.f. induced in the coil.

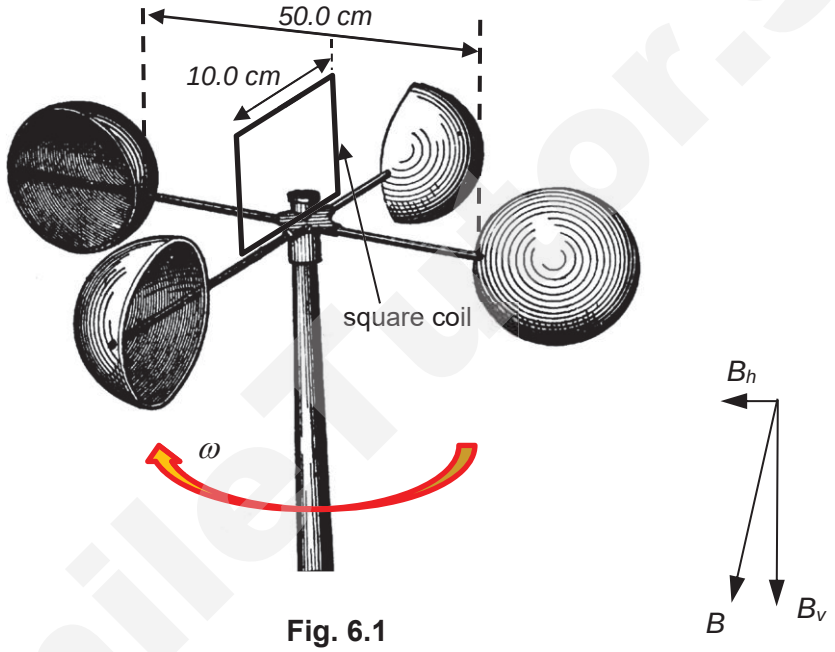

Fig. 6.1

Assume that the horizontal B_h and vertical B_v components of the earth's magnetic field B are 1.5×10^{-5} Wb m^{-2} and 5.5×10^{-5} Wb m^{-2} respectively.

(i) Explain why an e.m.f. is generated when the coil rotates in the earth's magnetic field.

……

……

……

…… [2]

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(ii) Explain briefly why the e.m.f. is sinusoidal when the anemometer rotates with constant angular velocity ω.

……

……

……

…… [2]

(iii) If the maximum wind velocity to be measured is 200 km h^{-1}, find the angular velocity of the rotation of the cups, ω.

ω = …… rad s^{-1} [1]

(iv) State an expression for the maximum e.m.f. induced, ε_{max} during rotation of the coil in terms of ω, B_h, n and A where n is number of turns of the coil and A is area of the square coil.

ε_{max} = …… [1]

(v) Hence calculate the number of turns of the coil, n, if the maximum induced e.m.f. is 15 mV.

n = …… [1]

(vi) Briefly state and explain if there will be any potential difference across the two ends of each 50.0 cm metal rod during rotation at maximum speed.

……

……

……

…… [2]

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Section B

Answer **ONE of** the two questions in this section in the spaces provided.

7 (a) A tube, sealed at one end, has a uniform area of cross-section A. Some sand is placed in the tube so that it floats upright in a liquid of density ρ, as shown in Fig. 7.1. The tube has total mass m of 32 g and the area A of its cross-section is 4.2 cm^2.

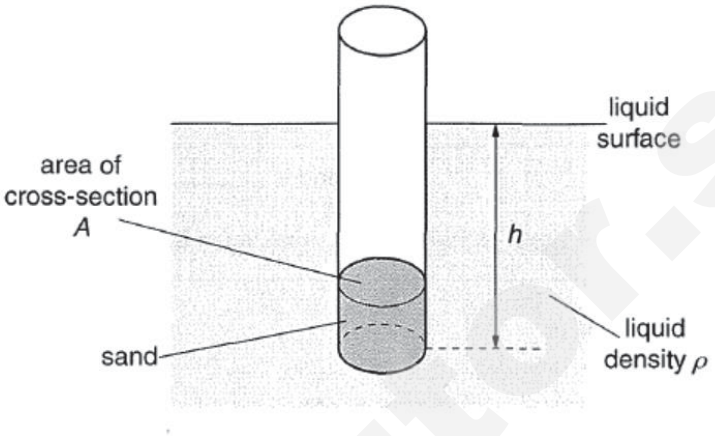

Fig. 7.1

The tube is displaced vertically and then released. For a displacement x, the acceleration a of the tube is given by the expression

$$a = -\left(\frac{\rho A g}{m}\right)x$$

where g is the acceleration of free fall.

The tube experiences damped oscillations in the liquid as shown in Fig. 7.2.

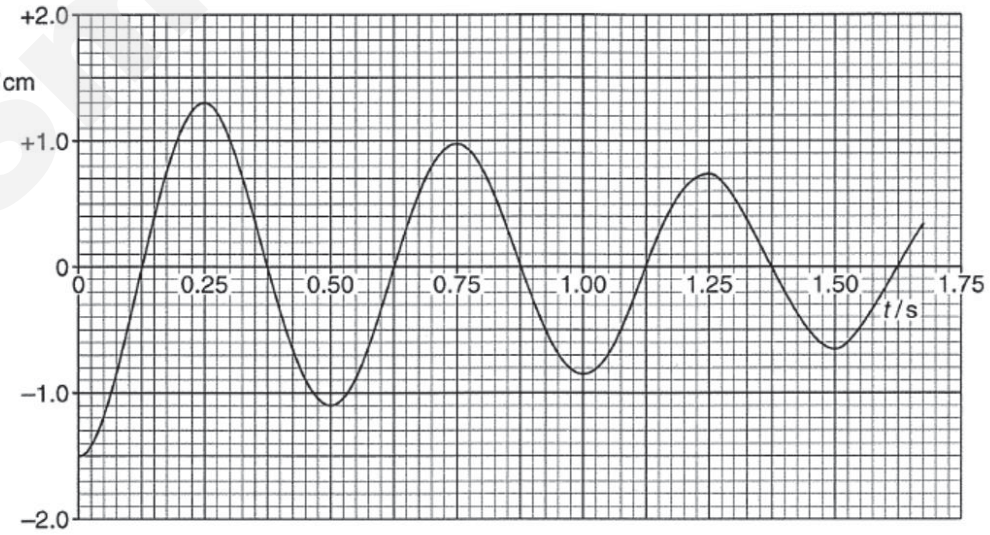

Fig. 7.2

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(i) Determine the frequency of the oscillation.

frequency = …… Hz [1]

(ii) Calculate the density of the liquid.

density = …… kg m^{-3} [3]

(iii) Calculate the percentage loss of the energy of the oscillation during the first 1.50 seconds.

energy loss = _____ % [3]

(iv) The tube is now placed in a liquid which is more viscous. It starts to oscillate from the same displacement at t = 0.00 s.
Explain in terms of energy changes why the amplitude of oscillation in this liquid decreases more over the same period.

……

……

……

……

…… [2]

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(b) (i) Describe the difference between a travelling wave and a stationary wave in terms of their amplitudes of vibration and energies.

……

……

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…… [3]

(ii) A stationary microwave is formed between a microwave source at A and a reflector at B, as illustrated in Fig. 7.3.

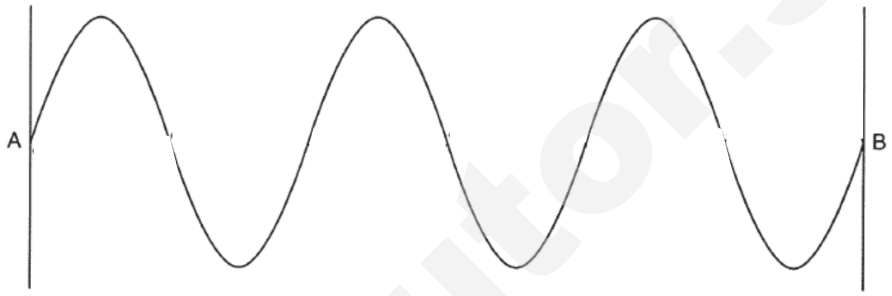

Fig. 7.3

At time t = 0, the standing wave is at its amplitude position as shown by the solid line in Fig. 7.3.

Sketch on Fig.7.3 the shape of the wave

1. when $t = T/8$. Label this wave as shape X.

2. when $t = 3T/4$. Label this wave as shape Y.

3. when $t = 5T/8$. Label this wave as shape Z.

[3]

(c) A student wishes to measure the separation of two narrow parallel slits.
A beam of laser light of wavelength 633 nm is directed normally at the plane of the slits. The light emerging from the slits is viewed on a screen placed 2.95 m away from the slits.
Part of the fringe pattern observed on the screen, together with a measurement for the width of some fringes, is shown in Fig. 7.4.

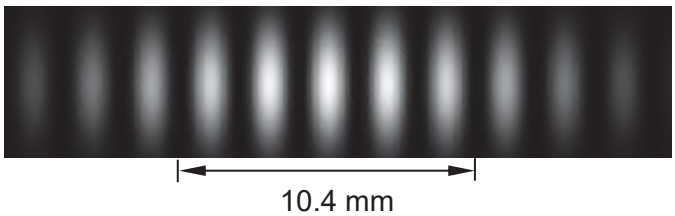

Fig. 7.4 (not to scale)

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(i) Determine the separation, in mm, of the slits.

slit separation = …… mm [2]

(ii) The student wishes to compare the fringe pattern with when an identical beam of light passes through a diffraction grating of 100 lines / mm under the same conditions.

State three changes the student will observe.

……

……

……

……

……

…… [3]

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8 Cobalt-60, an isotope widely used in medicine, decays by emitting an electron (β^- decay) with a half-life of 5.272 years into an excited state of nickel-60, which then de-excites very quickly to the ground state of nickel-60 by emitting a number of gamma photons.

(a) **(i)** Complete the nuclear equation for the Co-60 decay below.

$$^{60}_{\ldots\ldots}\mathrm{Co} \rightarrow {}^{\ldots\ldots}_{28}\mathrm{Ni} + {}^{\ldots\ldots}_{\ldots\ldots}\mathrm{e} + \gamma$$

[2]

(ii) Determine the number of nuclei in 1.00 g of Cobalt-60.

Number of nuclei = ... [1]

(iii) The total energy released in each Co-60 decay is 2.8 MeV. Hence, show that the initial radiation power for Co-60 is 19 W g^{-1}.

[2]

(b) The emission spectrum of the gamma photons emitted due to the de-excitation of nickel-60 are shown in Fig. 8.1.

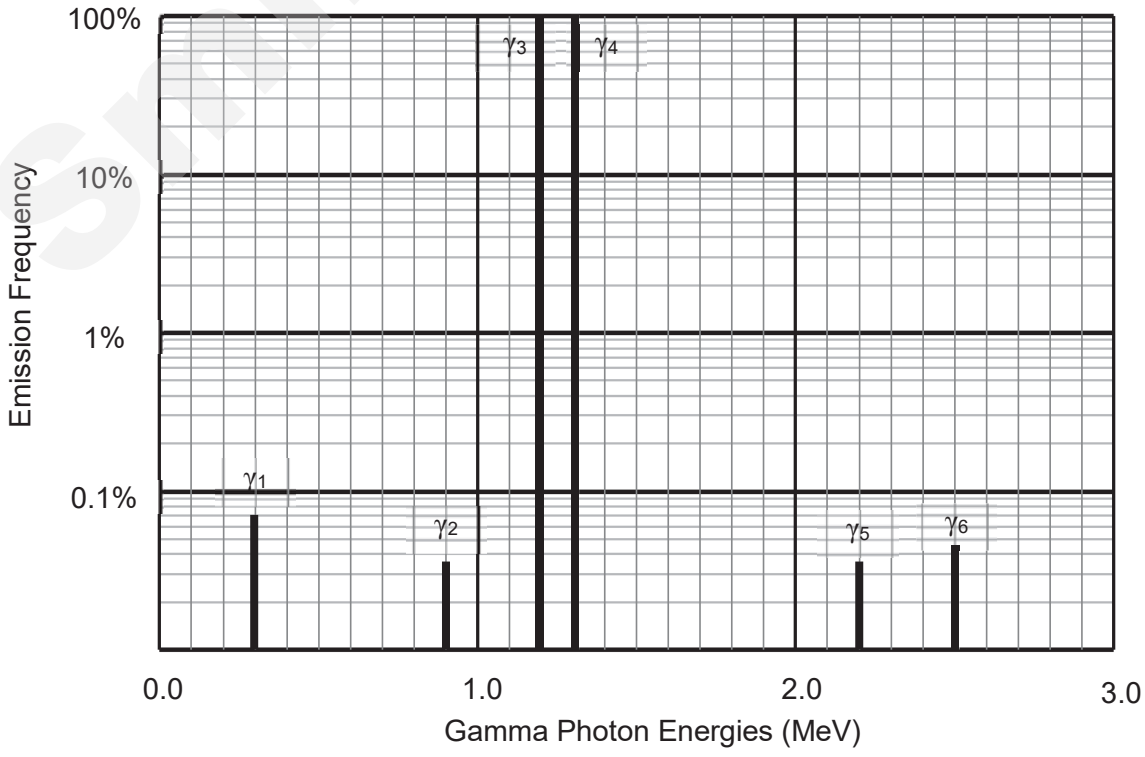

Fig. 8.1

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(b) **(i)** Explain what is meant by a *gamma photon*.

……

…… [2]

(ii) Calculate the momentum of gamma photon associated with spectral line γ_4.

momentum = ……N s [2]

(iii) Explain why Fig. 8.1 provides evidence that the nucleus has discrete energy levels.

……

……

……

…… [2]

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(iv) The energy levels of the nucleus of nickel-60 are shown in Fig. 8.2.

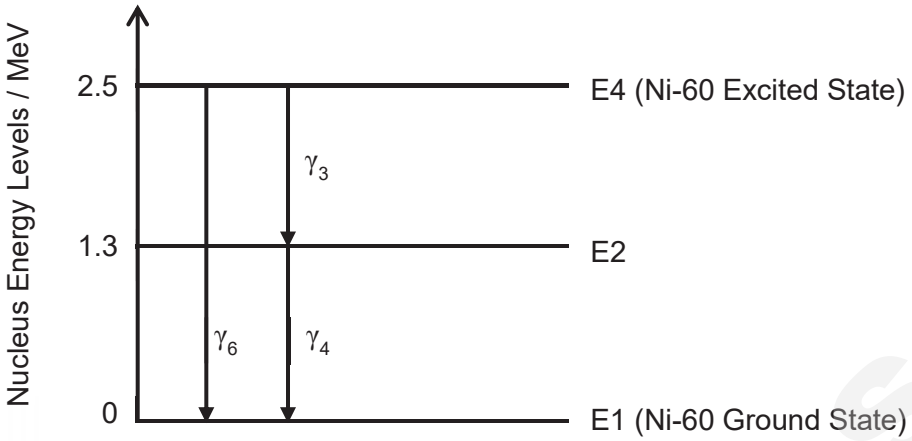

Fig. 8.2

1. There is a missing energy level in Fig. 8.2. With reference to Fig. 8.1, draw and label the missing energy level, and fill in the transitions corresponding to γ_1, γ_2, and γ_5.

[2]

2. The rest-mass of the Ni-60 nucleus at the ground state E1 is 59.93079*u*. Calculate the mass of the Ni-60 nucleus at its excited state E4. Explain the principle behind your calculation.

mass = ……*u*

……

…… [3]

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(c) Co-60 sources are often kept in lead containers. The interaction between the β^- particles and the lead atoms give rise to Bremsstrahlung and characteristic X-ray radiation.

(i) By considering the energy of the β^- particles and an excited nickel-60 nucleus, calculate the cut-off wavelength of the Bremsstrahlung radiation.

wavelength = ……m [2]

(ii) Explain the origin of the **characteristic** X-ray.

……

……

……

…… [2]

End of Paper

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HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**16S**
TUTOR NAME			

PHYSICS

9749/04

Paper 4 Practical

23 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paperclips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/ 15**
2	**/ 8**
3	**/ 20**
4	**/ 12**
Total	**/ 55**

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1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100g of salt as shown in Fig. 1.1.

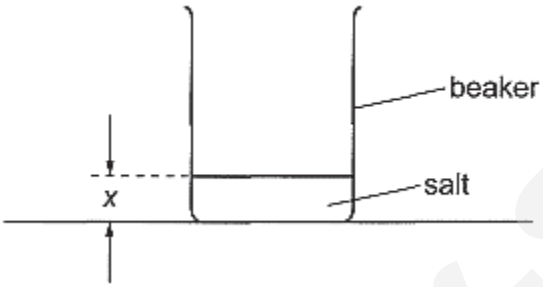

Fig 1.1

(i) Measure and record the depth x of salt in beaker **P** using the vernier caliper.

x = ... [2]

(ii) Estimate the percentage uncertainty in your value of x.

percentage uncertainty = ... [1]

(b) You have been provided with two cards. Each card has a hole of different size.

(i) Measure and record the diameter d of the **smaller** hole.

d = ... [1]

(ii) Determine the area A of the **smaller** hole.

A = ... [1]

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(c) **(i)** Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

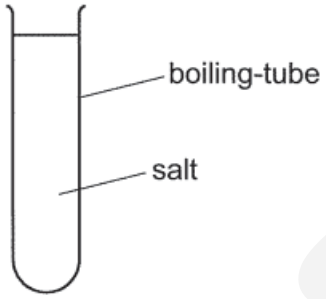

Fig. 1.2

(ii) Cover the open end of the boiling-tube with the card that has the **smaller** hole.

Use tape to attach the card to the boiling-tube.

The hole should not be covered by tape. When the boiling-tube is inverted it should not be possible for salt to leave the boiling-tube other than through the hole.

(iii) Invert the boiling-tube over the empty beaker **Q**. Measure the time taken for ALL the salt to flow through the hole into beaker **Q**.

It may be necessary to shake the boiling-tube gently from time to time to achieve constant flow.

Time taken = ...

(iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level.

Measure and record the depth *x* of salt in beaker **Q**.

x = ...

(v) Estimate the mass *m* of salt in beaker **Q**.

m = ... [1]

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(d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker with a hole the same size as that in **(c)(ii)** should be inverted to apply 5 g of salt to food.

time taken = ... [1]

(e) It is suggested that the rate of flow of salt R is proportional to the area A of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

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.....

.....

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.....

..... [6]

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(f) A statement found on the internet says that:

"*The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However, there is no manufacturing standard.*"

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

……

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……

…… [2]

[Total: 15 marks]

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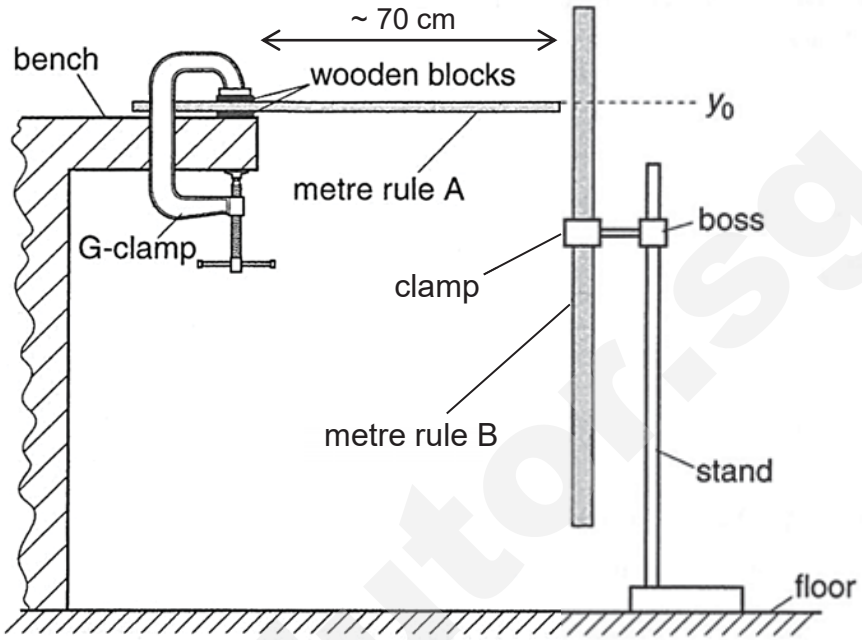
2 In this experiment you will investigate the deflection of a loaded metre rule.

(a) **(i)** Set up the apparatus as shown in Fig. 2.1.



y_0 is the point on rule B level with the top of rule A.

Fig. 2.1

(ii) Record the reading y_0.

y_0 = ... [1]

(iii) Place a 200 g mass on the end of rule A as shown in Fig. 2.2.

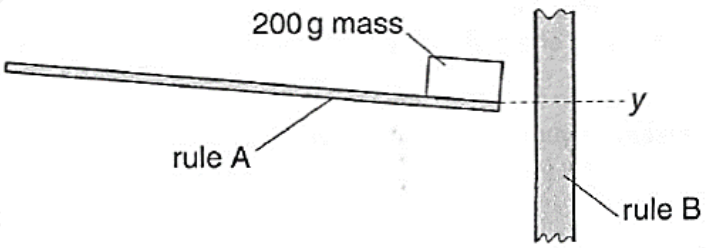


Fig. 2.2

y is the point on rule B level with the top of rule A.

(iv) Record the reading y.

y = ... [1]

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(v) Remove the 200 g mass from rule A.

(vi) Calculate the deflection $(y - y_0)$.

$(y - y_0) =$ ..... [1]

(vii) Determine the percentage uncertainty in $(y - y_0)$

percentage uncertainty in $(y - y_0) =$ ..... [1]

(b) **(i)** Repeat **(a)(ii)**.

$y_0 =$ .....

(ii) Place the 200 g mass at a position approximately halfway along rule A.

(iii) Repeat **(a)(iv)**, **(a)(v)** and **(a)(vi)** with the 200 g mass placed at a position approximately half way along rule A.

$y =$ ....

$(y - y_0) =$ .....

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(c) **(i)** it is suggested that:

"if both masses are placed on rule A in different positions at the same time, the deflection will equal the sum of the deflections for each mass on its own."

Take more readings to investigate this suggestion. Present your results in a table. [2]

(ii) State whether or not the results of your experiment support the suggestion.

Justify your answer by referring to your calculated percentage uncertainty in **(a)(vii)**.

……

……

……

……

…… [1]

(d) **(i)** State a significant source of error in this experiment.

……

……

……[1]

(ii) Suggest one improvement that could be made to the experiment to address the source of error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

……

……

…… [1]

[Total: 8 marks]

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You may not need to use all of the materials provided.

3 In this experiment, you will determine the resistivity of a metal in the form of a wire.

(a) (i) Measure and record the diameter d of the short sample of wire that is attached to the card. You may remove the wire from the card.

d = ... [1]

(ii) Calculate the cross-sectional area A of the wire, in m^2, using the formula

$$A = \frac{\pi d^2}{4}$$

A = ... m^2

(b) (i) Use the wire attached to the metre rule, one of the voltmeters and one of the resistors to set up the partial circuit shown in Fig. 3.1.

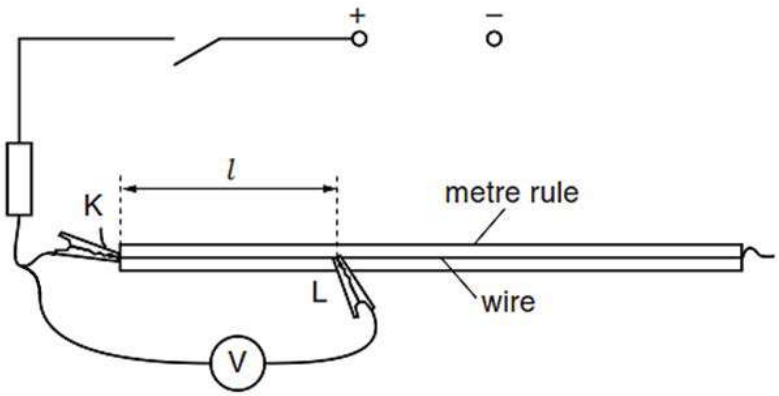

Fig. 3.1

There are two crocodile clips, one labelled K and the other labelled L.
Place K and L so that the distance l between them is approximately 30 cm.

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(ii) Measure and record the distance l between K and L.

l = ...m

(iii) Use the other resistor and the other voltmeter to complete the circuit shown in Fig. 3.2.

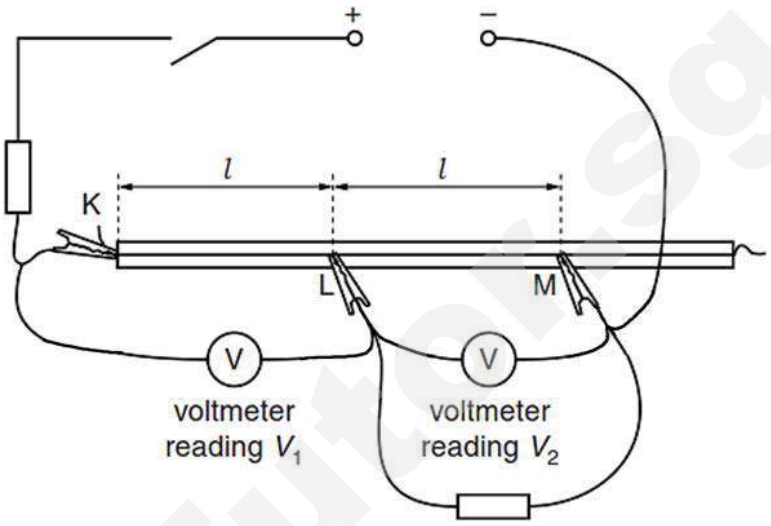

Fig. 3.2

(iv) Place the crocodile clip M at a distance l from L. The value of l should be the same as in **(b)(ii)**.

(c) **(i)** Switch on the power supply.

(ii) Record the voltmeter readings V_1 and V_2 as shown in Fig. 3.2.

V_1 = ...V

V_2 = ...V
[1]

(iii) Switch off the power supply.

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(d) Repeat steps **(b)(ii)**, **(b)(iv)** and **(c)** to obtain further sets of readings for l, V_1 and V_2. For each set of readings, l should be greater than 20 cm, while distances KL and LM should both be l.

[7]

(e) Theory suggests that l, V_1 and V_2 are related by the equation

$$\frac{V_1}{V_2} = Pl + Q$$

where P and Q are constants.

Plot a suitable graph to determine P and Q.

P = ...

Q = ...[4]

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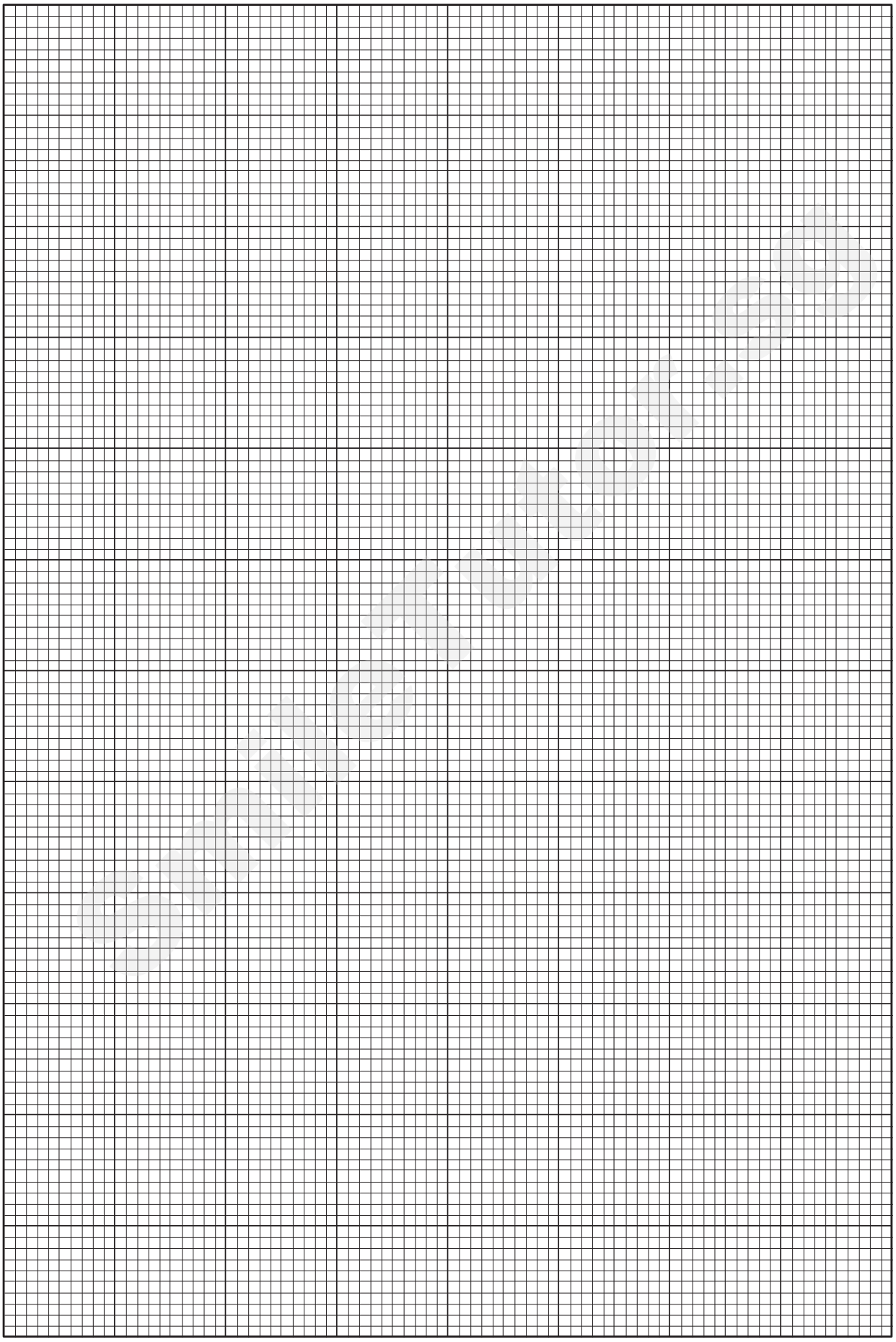

[3]

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(f) Comment on any anomalous data or results that you may have obtained. Explain your answer.

……

……

……[1]

(g) The resistivity ρ of the material of the wire, in Ω m, can be found using the relationship

$$\rho = PAR$$

where R = 10 Ω

Use your answers in **(a)(ii)** and **(e)** to calculate a value for ρ.

ρ = ... Ω m [1]

(h) **(i)** State one significant source of error in this experiment.

……

……...[1]

(ii) Suggest an improvement that could be made to the experiment to address one of the sources of error identified in **(h)(i)**. You may suggest the use of other apparatus or a different procedure.

……

…… [1]

[Total: 20 marks]

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CANDIDATE NAME		CT GROUP	16S

4 Concrete is widely used for construction and its manufacture contributes 5% to the world's carbon dioxide (CO_2) production. One way of reducing the amount of CO_2 produced could be to use less cement in the production of concrete.

A company is producing concrete with low cement content and wishes to see how the material behaves under a compressive force. A compressive force applied to a concrete object will reduce the length of the object in the direction of the force very slightly.

The reduction in length of the object is to be measured using a strain gauge.

When a wire has its length changed, its resistance changes. A strain gauge consists of a length of thin wire as shown in Fig. 4.1.

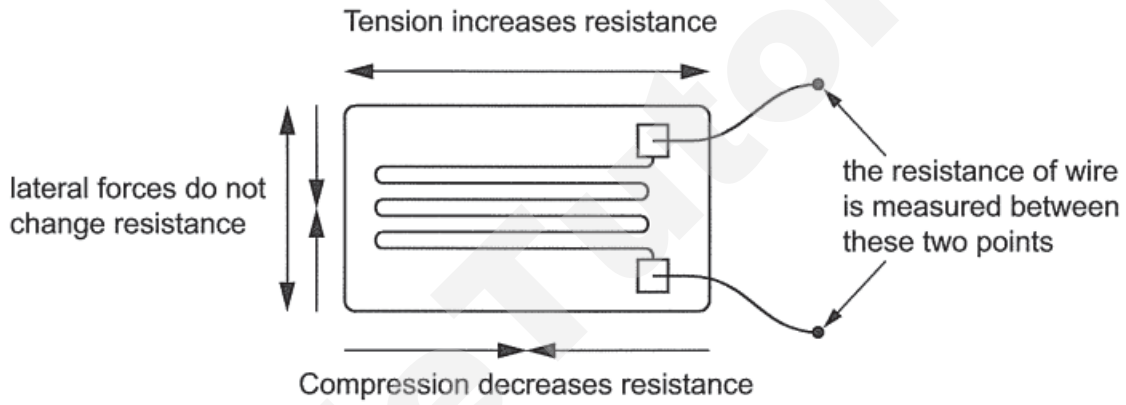

Fig. 4.1

The gauge consists of a wire wound backwards and forwards and embedded in thin plastic. The plastic is then bonded firmly to the specimen being investigated.

The relation between change in resistance ΔR and change in force ΔF is

$$\Delta R = k\,(\Delta F)^n$$

where k and n are constants.

You are provided with some heavy masses, a low voltage power supply and other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of n for compressive forces applied to a small concrete cylinder along its axis.

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the compressive force and change in resistance are measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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2017 HCI Prelim Exam H2 Physics 9749 P4 (Practical) Preparation List

Question 1

Apparatus List:

1	Two identical 250 ml beakers. One of the beakers should contain 100 g of fine salt and be labelled P. The other should be labelled Q. See **Note 1**.
2	Boiling-tube of approximate length 15cm and approximate diameter 2.5cm.
3	Stopwatch reading to 0.1 s or better.
4	Manual vernier caliper reading to 0.1 mm with a depth probe.
5	Two circular pieces of thin card. See **Note 2.**
6	Small roll of adhesive tape.
7	Scissors.
8	One filter funnel
9	Tray with approximate dimensions 30cm x 40cm x 5cm.

Notes

1 The salt must be in loose grains and should be prepared only on the day of assessment.

2 The card should be of approximate thickness 0.2 mm. 140 gsm paper is suitable. The pieces of card should be of the same size as the open end of the test tube (including the 'lip'). Each card should have a central circular hole as shown in Fig. 1.



Fig. 1

One hole should be of approximate diameter 3 mm. This could be made with a nail of approximate diameter 6 mm. The other hole should be made with a hole-punch to yield a hole of approximate diameter 8 mm.
Candidates are entitled to ask for replacement cards during the test.
If the apparatus is to be used by a second candidate, it should be restored to its original state with new cards supplied.

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Question 2

Apparatus List:

1	One large G-clamp
2	Two metre rules each with the smallest division of 1 mm (See Note(i))
3	Two small wooden blocks. (See Note (ii))
4	Two 200 g masses. See Note (iii)
5	One stand, one boss and one clamp.

Notes

(i) One of the metre rules should be clearly labelled 'A'. The other metre rule should be clearly labelled 'B'.

(ii) The wooden blocks should enable a metre rule to be held firmly to the bench or table top using the G-clamp as shown in Fig. 1.1.

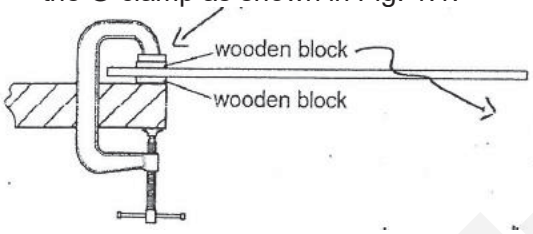

Fig. 1.1

(iii) Each 200 g mass should consist of two 100 g slotted masses taped together. Each 200 g mass should be labelled '200 g'.

(iv) The apparatus should be laid out on the bench unassembled. The Supervisor should ensure that each candidate has sufficient space to perform the experiment. A distance of at least 1.2 m beyond the edge of the bench is required.

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Question 3

Apparatus List:

1	Low voltage power supply fixed at 1.5 V d.c.
2	Two digital voltmeters set to the range 0 – 2 V reading to the nearest 0.001 V. If digital multimeters are used, the range should be fixed and any unused terminals should be covered.
3	30 cm ruler with a millimetre scale.
4	Metre rule with a millimetre scale. See Note 1.
5	110 cm length of 36 swg constantan wire. See Notes 1 and 2.
6	20 cm length of 36 swg constantan wire taped to a card and labelled 'sample of wire'. See Note 2.
7	Two 10 Ω resistors each in a component holder with terminals.
8	Eleven connecting leads. See Note 3.
9	Switch.
10	Access to a micrometer screw gauge.

Notes

1 The 110 cm length of wire should be attached to the metre rule with 5 cm protruding at each end. It should be possible to attach a crocodile clip to each end of the wire. The wire should be attached to the rule firmly enough (e.g. using adhesive tape at the ends of the rule) to minimise any looseness or kinks.

2 If 36 swg constantan wire is unavailable then 32 swg nichrome wire may be used.

3 Three of the leads should have a length of at least 0.5 m and should each have a crocodile clip attached to one end.

The crocodile clips should be labelled K, L and M. It should be possible to connect several leads together, for example with stackable plugs.

4 The apparatus should be laid out on the bench. If the apparatus is to be used by another candidate, then it should be restored to its original state.

If the sample of wire has been removed from the card, it should be re-attached.

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2017 HCI Prelim H2 Physics Paper 1 Answers and Solutions

1	**D**	6	**C**	11	**C**	16	**B**	21	**D**	26	**C**
2	**C**	7	**B**	12	**B**	17	**A**	22	**C**	27	**D**
3	**C**	8	**B**	13	**A**	18	**C**	23	**A**	28	**A**
4	**C**	9	**B**	14	**A**	19	**B**	24	**C**	29	**C**
5	**B**	10	**C**	15	**B**	20	**D**	25	**A**	30	**A**

1 D

$37.86\times10^{-4}\ \text{MJ cm}^{-4} = 37.86\times10^{-4}\ 10^{6}\ \text{J}\ (10^{-2}\ \text{m})^{-4}$

$= 37.86\times10^{-4}\times10^{8}\times10^{6}\ \text{J m}^{-4}$

$= 3.786\times10^{11}\ \text{m}^{-4}\text{J} = 378.6\times10^{9}\ \text{J m}^{-4}$

$= 378.6\ \text{GJ m}^{-4}$

2 C

Estimate the population as 6 million people and the land as 700 km^2.

$$\frac{6\times10^{6}}{7\times10^{2}\ \text{km}^2}\approx10^{4}\ \text{km}^{-2}$$

3 C

The distance travelled by each vehicle is given by the area under their respective graphs.

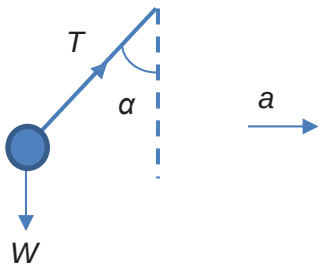
For both car and lorry, the distance travelled between 0 and 40 seconds is the same at 400 m.

This means the separation distance is zero at 40 s, which is also the least distance.

4 C

Option A: True. At the uniform speed the rope does not experience any horizontal acceleration. Hence, the angle is zero.

Option B: True.



$T \sin\alpha = ma$
$T \cos\alpha = W = mg$
$\tan\alpha = a / g$

Option C: False. Tension is W / sin α when it is accelerates. Tension is equal to W when it moves with a uniform speed. W / sin α > W

Option D: True. When the car decelerates, the net horizontal force is leftwards which swings the rope to the right.

5 B

Since the railway platform is in contact with the Earth, the Earth absorbs the vertical momentum, vertical component of the recoil is negligible.

Thus, considering the horizontal (x) components,
by PCOLM,

$P_{1x} = -P_{2x}$ 1: bullet 2: gun
$M_1v_1\cos45° = -m_2v_{2x}$
$v_{2x} = -(500)(200)\cos45° / 70000 = -1.01\ \text{ms}^{-1}$

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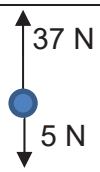
6	**C**	Raw Power input = Rate of GPE converted to Electrical Energy $= \frac{mgh}{t}$ $= \frac{\rho Vgh}{t}$ $= \frac{1000(6.0)(9.81)(80)}{1\,\text{sec}}$ = 4.7088 MW Since Efficiency $= \frac{P_{out}}{P_{in}} = 0.60$ Then P_{out} = 0.60 x 4.7088 = 2.8 MW
7	**B**	The driving force by the propeller equals the drag force on the boat when the boat is at constant speed. $P_{engine} = F_{engine}v = F_{drag}v$ $30000 = F_{drag}(15.0)$ $F_{drag} = 2000$ N Since $F_{drag} = kv^2$ $2000 = k\,(15.0)^2$ So drag constant k = 8.889 When v = 5.0 m s^{-1}, $F_{drag} = kv^2 = 8.889 \times 5.0^2 = 222$ N When the boat is being towed at constant speed at 5.0 m s^{-1}, the drag force equals the towline tension.
8	**B**	Maximum tension and speed occurs at the bottom of the vertical circular path. (resultant) Centripetal force is upwards. $F_{net} = ma_c = mr\omega^2$ $37 - 5 = 0.5\,(4.00)\,\omega^2$ ω = 4.0 rad s^{-1} 
9	**B**	For a mass, m, projected from a planet of mass M and radius r with escape velocity, v_{esc} : $\frac{1}{2} mv_{esc}^2 - GMm / r = 0$ $v_{esc} = \sqrt{\frac{2GM}{r}}$ $(v_{esc})_{Earth} / (v_{esc})_{Mars} = \sqrt{\frac{M_{Earth}}{R_{Earth}}} / \sqrt{\frac{M_{Mars}}{R_{Mars}}} = \sqrt{\frac{M_{Earth}}{R_{Earth}}\frac{R_{Mars}}{M_{Mars}}}$
10	**C**	Acceleration due to gravity at the surface of a planet of mass M and radius R, $g = \frac{GM}{R^2} = \frac{G(\rho\frac{4}{3}\pi R^3)}{R^2} = G\rho\frac{4}{3}\pi R$ $\frac{g_X}{g_Y} = \frac{\rho_X R_X}{\rho_Y R_Y} = \frac{2R_Y}{R_Y} = 2$

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11 **C**

Heat lost by water = Heat gained by ice to just melt,
$M_{water}c_{water}(T - 0) = M_{ice}c_{ice}\Delta T + m_{ice}L_f$

$$T = \frac{2.0(2100)(20) + 2(3.35\times10^5)}{4.0(4200)} = 45°C$$

12 **B**

From the formula list: $P = \frac{1}{3}\rho v_{rms}^2$

Therefore, 100 000 = 0.178 v_{rms}^2 / 3

v_{rms} = 1298 m s^{-1} = 1300 m s^{-1}

13 **A**

For an ideal gas, PV = Nrt

Hence, $\frac{V_2}{V_1} = \frac{T_2}{T_1}$

$$\frac{100\times10^{-3}}{25\times10^{-3}} = \frac{T_2}{200}$$

T_2 = 800 K.

Since $U = \frac{3}{2}nRT$

$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(1)(8.31)(800-200) = 7479 \text{ J}$$

Other possible distractors: 5000 J (use PΔV with P = nRT/V = 66480 Pa)

14 **A**

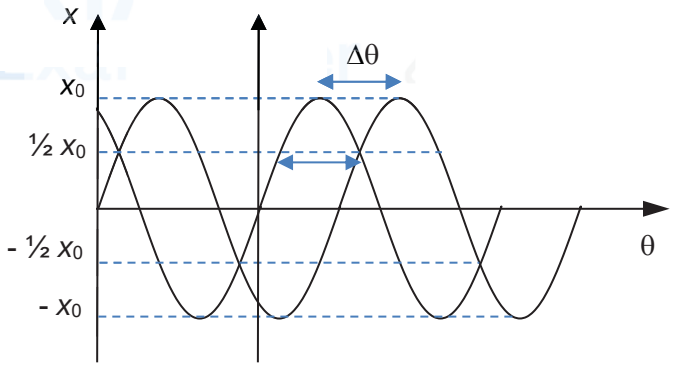
Δ*U* is negative.
At freezing point, temperature is constant, thus microscopic KE remains unchanged, but molecules are held more strongly together by intermolecular forces of attraction, the microscopic PE decreases.

q is negative as heat flows out of the system.
w is positive as the substance contracts, volume decreases thus *p*Δ*V* < 0.

15 **B**

Since we are determining phase difference, it is easier to work directly in x- θ equation instead of x-t equation.

Determine the phase angle such at x = x_0/2: $x_0/2 = x_0 \sin\theta \Rightarrow \theta = \sin^{-1}(½) = 30°, 150°$



Δθ = 150° - 30° = 120°

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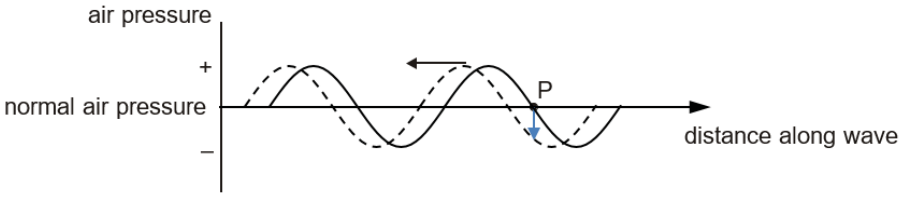
16 **B**

The pressure variation "moves" along with the energy, compression and rarefaction will move to the left.



17 **A**

Beyond A, the light intensity is always I .
B lets all of the light from A go through, implies that the axes of polarization of A and B are parallel.

With C between A and B:

angle between the axis of A and the axis of C = angle between the axis of C and the axis of B = θ

Beyond C, applying Malus' Law:

$$I_C = I\cos^2\theta$$

Beyond B, applying Malus' Law:

$$I_B = I_C\cos^2\theta$$

$$\frac{2I}{3} = \left(I\cos^2\theta\right)\cos^2\theta = I\cos^4\theta$$

$$\cos^4\theta = \frac{2}{3}$$

$$\theta = \cos^{-1}\left(\frac{2}{3}\right)^{\frac{1}{4}} = 25.4°$$

18 **C**

The longitudinal stationary wave will form a displacement node at the closed (water) end and a displacement antinode at the open end (loudspeaker, with vibrating diaphragm)

19 **B**

$V_1 = V_2$

$$\frac{kq_1}{r_1} = \frac{kq_2}{r_2}$$

$$\frac{q_1}{q_2} = \frac{r_1}{r_2}$$

$$\frac{E_1}{E_2} = \frac{kq_1/r_1^2}{kq_2/r_2^2} = \frac{q_1}{q_2}\times\frac{r_2^2}{r_1^2} = \frac{r_2}{r_1}$$

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20	**D**	For the same p.d. V, resistance of wire decreases when its diameter decreases, since $R = \frac{\rho l}{A}$, and current increases as I is proportional to A as $I = \frac{V}{R} = \frac{AV}{\rho l}$. Comparing with current $I = nv_d qA$ $\Rightarrow I$ is proportional to A or d^2, v_d remains the same as it is independent of d.
21	**D**	Compute the effective resistance for each case. D having the smallest resistance draw the largest current.
22	**C**	By potential divider principle, increasing resistance of R will decrease the p.d. across the potentiometer wire, and resulting in smaller p.d. per unit length. Thus balance point will be nearer to M.
23	**A**	The point charge's velocity is parallel to resultant magnetic flux density at the centre of the two wires. Thus magnetic force is zero.
24	**C**	To find maximum instantaneous speed: $mg\Delta h = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh} = \sqrt{2(9.81)(0.274)} = 2.32$ m s^{-1} maximum average speed = $\left(\frac{v}{2}\right) = 1.16$ m s^{-1} maximum induced e.m.f. = $Bl\left(\frac{v}{2}\right) = 1.5(0.800)(1.16) = 1.4$ V
25	**A**	Since inner loop experiences decreasing flux linkage, current in the inner wire will flow in the same direction as that in the outer wire to oppose this deceasing flux linkage (Lenz's law). Since the rate of decrease of current with time is constant, the rate of decrease of B and hence flux linkage is constant, hence e.m.f. induced in inner loop is constant and the current in the inner loop is constant.
26	**C**	For sinusoidal a.c. V_{rms}(a) = V_{peak} / √2 For the case of full square wave ac, <P> = V^2_{peak} /R Half-wave rectified square wave ac, <P'>= V^2_{peak} /2R V^2_{rms} /R = V^2_{peak} /2R V_{rms}(b) = V_{peak} / √2 Thus the ratio is 1.

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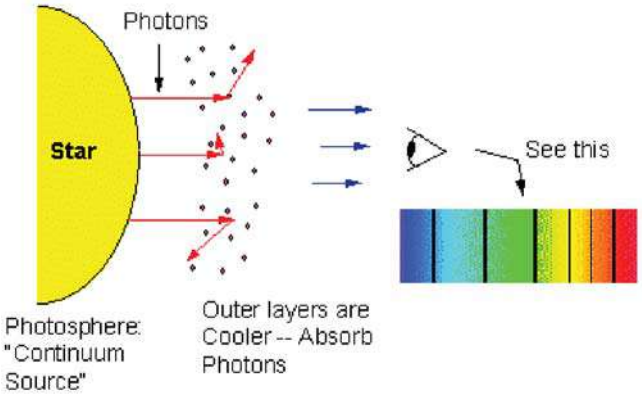
27	**D**	In the solar absorption line spectra, the dark lines are caused by photons being absorbed by elements in the cooler photosphere, to excite to higher energy states. 
28	**A**	By conservation of energy, KE gained by electron = ePE lost by electron $\frac{p^2}{2m} = eV \Rightarrow \frac{\left(\frac{h}{\lambda}\right)^2}{2m} = eV$ $\lambda = \frac{h}{\sqrt{2meV}}$ when V is doubled, $\lambda' = \frac{h}{\sqrt{2me2V}} = \frac{h}{\sqrt{2}\sqrt{2meV}}$ $\frac{\lambda' - \lambda}{\lambda} = \frac{\frac{h}{\sqrt{2}\sqrt{2meV}} - \frac{h}{\sqrt{2meV}}}{\frac{h}{\sqrt{2meV}}} = \frac{\frac{1}{\sqrt{2}} - 1}{1} = -0.29 = -29\%$
29	**C**	Energy is released in nuclear fusion (not fission) reactions from nuclei in region P.
30	**A**	${}^{8}_{3}\text{Li} \rightarrow {}^{8}_{4}\text{X} + {}^{0}_{-1}\text{e}$ ${}^{8}_{4}\text{X}$ has 4 protons and 4 neutrons, corresponding to A.

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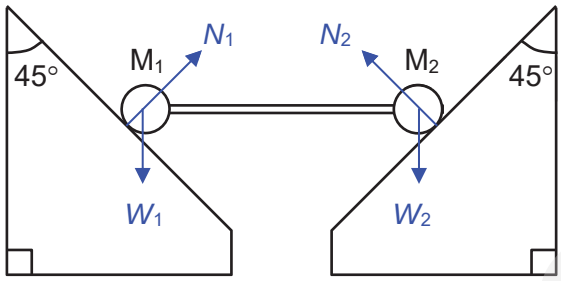
JC2 HCI H2 Physics Prelim Paper 2 Suggested Solutions

1	**a)**		Net force acting on the body is zero Net torque /moment acting on the body about any point is zero	B1 B1
	b)		Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.	
		(i)	 **Fig. 1.1**	
			correct identification of forces correct orientation of forces (marker please decide)	B1 B1
		(ii)	$N\cos 45° = 2(9.81)$ $N = 27.7$ N	M1 A1
	(c)	**(i)**	Yes. The horizontal components of N1 and N2 must be equal in magnitude (so that horizontal net force is zero).	B0 B1
		(ii)	Consider moments about the intersection of N_1 and N_3. The clockwise moment produced by $4g$ is larger than the anti-clockwise moment produced by $2g$. OR Consider the lines of action of N_1, N_3 and $6g$. Since the C.G. lies closer to M_3 than M_1, the lines of action will not intersect at one point.	B1 B1

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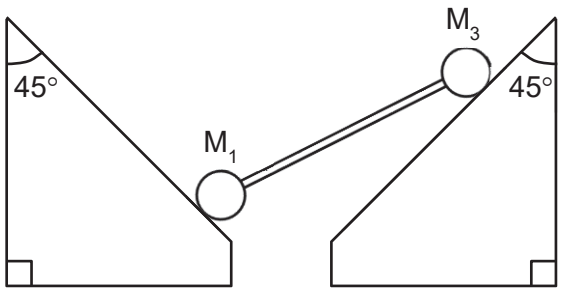
		(iii)	 **Fig. 1.2**	[1]

2(a)	The **gravitational field strength *g*** at a point is the *gravitational force per unit mass* acting on a small mass placed at the point.		[1]
(b)	**(i)**	Acceleration of the satellite = g at that point = $\frac{GM_E}{r^2}$	[1]
	(ii)	The gravitational force on satellite by Earth provides for the required centripetal force to keep the satellite in circular orbit.	[1]
		$\frac{GM_E m}{r^2} = mr\omega^2$	
		ω – angular velocity	
		Since $T = \frac{2\pi}{\omega}$, $\frac{GM_E m}{r^2} = mr(\frac{2\pi}{T})^2$	[1]
		$T^2 = \frac{4\pi^2 r^3}{GM_E}$	
		$T^2 \propto r^3$ (Shown) and constant of proportionality is $\frac{4\pi^2}{GM_E}$	[1]
	(iii)	Period for geostationary satellite, T = 24 h = 24 x 60 x 60 s = 86400 s	[1]

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		Angular velocity, $\omega = \frac{2\pi}{T}$ = 7.3 x 10^{-5} rad s^{-1}	
	(iv)	$r^3 = \frac{GM_E}{\omega^2} = \frac{(6.67\times10^{-11})(6.0\times10^{24})}{(7.3\times10^{-5})^2}$ $r = (7.51\times10^{22})^{1/3}$ = 4.22 x 10^7 m Thus, altitude = $r - R_E$ = 3.6 x 10^7 m	[1] [1] [1]
	(v)	One possible use is for communication purpose to a particular region on Earth where there is a line of sight to the satellite. The geostationary satellite is always at a fixed position above the Earth and this ensure an uninterrupted communication channel with the satellite. Or For monitoring / spying a particular region on Earth below the satellite as the geostationary satellite is always at a fixed position above the Earth.	[2]

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3	**(a)**	At the equilibrium point, $F_{res} = 0 \rightarrow kx - mg = 0$ $kx = mg \rightarrow k = \frac{mg}{x}$, where x is the extension of spring. Any of these points or other correct points from the graph; When a mass of 150 g is hung, the extension on the spring is 10.0 cm. When a mass of 300 g is hung, the extension is 20.0 cm. When a mass of 450 g is hung, the extension is 30.0 cm $k = \frac{0.150g}{0.100} = 14.7$ N m^{-1}.	M1 M1 A0
	(b)	**(i)**	$\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{14.715}{0.450}} = 0.91$ Hz	M1 A1
		(ii)	$\Delta GPE = Mg(extension) = 0.450 \times 9.81 \times 0.300 = 1.32435$ J $\Delta EPE = \frac{1}{2}k(e_2^2 - e_1^2) = \frac{1}{2}(14.715)(0.400^2 - 0.100^2) = 1.103625$ J $\Delta KE = 1.32435 - 1.103625 = 0.220725$ J $0.220725 = \frac{1}{2}mv^2 \rightarrow v = 0.990$ m s^{-1} OR Note that question is asking for v for an oscillation with amplitude 20.0 cm at displacement of 10.0 cm. $v = \omega\sqrt{x_0^2 - x^2} = 2\pi(0.91)\sqrt{0.200^2 - 0.100^2}$	M1 M1 M1 A1
	(c)		The effective mass of the spring-mass system increases. The resonant frequency of heavier masses is at lower values of frequencies (or at greater periods). Hence, the frequency of the oscillation would be reduced. OR use $\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, deduce that f is inversely proportional to $\sqrt{m}$. When m increases, f is reduced.	M1 A1

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4	**(a)**		Diffraction is the spreading of waves (into their "geometrical shadows"), after passing through small apertures or round obstacles. Destructive interference is when two waves superpose/meet/overlap completely out of phase, resulting in a wave of zero (or reduced) amplitude.	B1 B1 B1 [3]
	(b)	(i)	$d \sin 90° \geq n\lambda$ $n \leq \frac{d}{\lambda} = \left(\frac{10^{-2}}{1000}\right)\left(\frac{f}{c}\right) = \left(\frac{10^{-2}}{3000}\right)\left(\frac{4.69 \times 10^{14}}{3.00 \times 10^{8}}\right) = 5.2$ $n = 5$ (correct d - 1, correct λ - 1) The possible number of maxima = 5 + 5 + 1 = 11	[2] [1]
		(ii)	$\sin\theta = \frac{n\lambda}{d} = n\left(\frac{3000}{10^{-2}}\right)\left(\frac{c}{f}\right) = 5\left(\frac{3000}{10^{-2}}\right)\left(\frac{3.00 \times 10^{8}}{4.69 \times 10^{14}}\right)$ $\theta = 73.6°$ $\tan 73.6° = \frac{x}{2.30}$ $x = 2.30 \tan 73.6° = 7.83$ m	[1] [1]
	(c)		$\sin\theta = \frac{n\lambda}{d}$ As green light has shorter wavelength, λ is decreased then sin θ also decreases. This means the separation between maxima will be closer.	[1]
	(d)		The diffraction grating causes sharper, brighter maxima, which spread out a lot more than a double slit. The bigger angle and better visibility give more accurate data to calculate the wavelength.	[1]

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5a) $KE_{max} = eV_s$

$= (1.60 \times 10^{-19})(1.15)$

$= 1.84 \times 10^{-19}$ J

b) $\frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{370 \times 10^{-9}}$

$= 5.38 \times 10^{-19}$ J

c) $KE_{max} = \frac{hc}{\lambda} - \Phi$

$1.84 \times 10^{-19} = 5.38 \times 10^{-19} - \Phi$

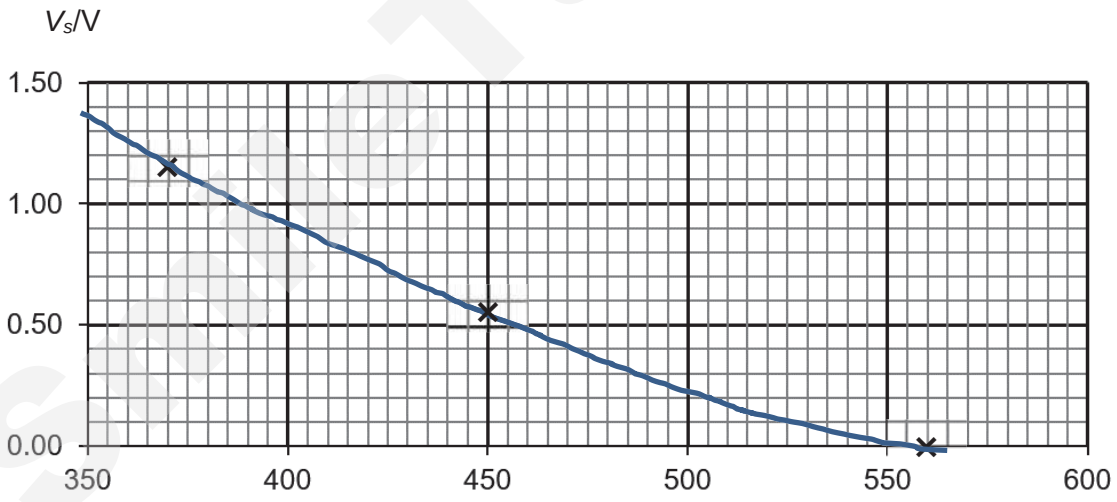
$\Phi = 3.54 \times 10^{-19}$ J

$\frac{hc}{\lambda_0} = \Phi$

$\frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda_0} = 3.54 \times 10^{-19}$

$\lambda_0 = 562$ nm

d)



B1 for (560, 0.00)

B1 for $\frac{1}{x}$ curve

e) There is no effect.

Doubling the intensity will double the rate of arrival of photons on the metal surface, but the energy of individual photon remains unchanged.

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6	**(a)**	**(i)**	Isotopes are atoms that have the same number of protons but different number of neutrons.	[1]
		(ii)	As the half-life of X (in years) is very long, the measured activity of sample X is thus relatively constant.	[1]
		(iii) 1	Decay constant of Y, $\lambda_Y = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{1.5 \times 60 \times 60}$ = 1.283 x 10^{-4} s^{-1}	[1]
		2	Equilibrium is reached when the rate of production of Y (from the decay of X) is equal to its rate of decay. Hence, the number of isotope Y in the sample will stabilise at a constant value.	[1]
		3	Thus, the activity of Y is about 1.1 x 10^7 Bq. Amount of Y, $N_Y = \frac{A_Y}{\lambda_Y} = \frac{1.1 \times 10^7}{1.283 \times 10^{-4}}$ = 8.6 x 10^{10} atoms	[1] [1]
	(c)	**(i)**	By $N = N_o e^{-\lambda t}$: $5N = 6Ne^{-\lambda t}$ Take ln on both sides, $\ln 5 = \ln 6 - \lambda t$ $t = \frac{\ln 6 - \ln 5}{1.570 \times 10^{-18}} = 1.161 \times 10^{17}$ s = 3.682 x 10^9 years = 3.7 x 10^9 years	[1] [1]
		(ii)	Decay of Th-232 will give rise to a radioactive series where there will be a number of radioactive daughter products before ending up as the stable Pb-208. It is assume that these intermediate radioactive daughter products have very short half-life (much shorter than that of Th-232) so the number of intermediate daughter products are insignificant compared to Th-232 and Pb-208.	[1]
		(iii)	If the assumption is not valid, the current amount of decay products will be more than 1N. The fraction of undecayed Th-232 is actually less than $\frac{5}{6}$, thus answer for **(b)(i)** will be an under-estimate.	[1]

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7 (a)	"per unit mass' is missing	[1]
(bi)	A turkey of twice the mass will have twice the volume. Since $V \alpha L^3$, $L \alpha \sqrt[3]{V}$ and so if volume is doubled L will increase by a factor of $\sqrt[3]{2} = 1.2599$ Since $A \alpha L^2$, A will increase by a factor of $\left(\sqrt[3]{2}\right)^2 = 1.5873$	[2]
(bii)	22 × 1.26 = 27.7 cm	[1]
(biii)	0.46/1.59 = 0.29 m^2	[1]
(ci)	$E = mc\Delta t = 9 \times 3200 \times 90 = 2.59MJ$	[2]
(cii)	$P = \frac{E}{t} = \frac{2590000}{2200} = 1200s$	[1]
(ciii)	Vast majority of heat is lost. Heat is lost to surroundings/ endothermic chemical reactions/change of state of water.	[2]

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(d)		Mass ×2 Surface area ×1/1.5873 Width ×1.2599 Scale factor is therefore given by 2× 1/1.5873 × 1.2599 = 1.59	[2]
(e)	(i)	Half width of 9 Kg turkey = 0.277/2 = 0.1385 m Area of 9 kg turkey = 0.46÷2=0.23 m^2 $\frac{\Delta Q}{\Delta t} = 0.6 \times 0.23 \times \frac{140}{0.1385} = 139W$	[3]
	(ii)	$t = \frac{E}{P} = \frac{2590000}{139} = 18633s = 5.18hours$	[1]
	(iii)	Since 18.0 kg turkey is double the mass of the 9.0 kg turkey the cooking time will increase by the same factor as before i.e. 1.59. Hence cooking time = 5.18×1.59 = 8.24 hours.	[1]
	(iv)	S. I units are W m^{-1} $^{\circ}C^{-1}$ Base units are kg m s^{-3} $^{\circ}C^{-1}$	[2]

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2017 HCI Prelim 9749 P3 Suggested Solution

Section A

1	**(a)**	**(i)**	Define *acceleration*. Acceleration is the rate of change of velocity with respect to time.	[1]
		(ii)	Use your definition in (a)(i) and the definition of average velocity, to show that for constant acceleration $v^2 = u^2 + 2as$ where v is the final velocity, u is the initial velocity, a the acceleration and t the time interval. For constant acceleration $a = \frac{v-u}{t}$ The displacement is given by $s = \left(\frac{v+u}{2}\right)t$ (average velocity x time) Rewriting, we get $\frac{1}{t} = \left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ and $a = (v-u)\left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ $2as = (v-u)(v+u)$ Hence $v^2 = u^2 + 2as$	[2]
	(b)	**(i)**	State the time at which the ball reaches its maximum height. Time = __1.15__ s	[1]
	(b)	**(ii)**	Determine the acceleration of the ball 0.5 s after leaving the thrower's hand. Determine the gradient of graph at t = 0.5 s Acceleration = __-17 m s^{-2}__ m s^{-2}	[2]

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	(b)	**(iii)**	Based on your answer in (b), determine the drag force on the ball 0.5 s after leaving the thrower's hand. Net force $F = W + F_{Drag} = ma$ $F_{Drag} = ma - mg = (0.320)(17.0) - (0.320)(9.81)$ [1] (Working) $= 2.30\ N$ [1] (Correct answer) Drag force = _____ N	[2]
	(b)	**(iv)**	Explain why the time taken to reach maximum height is less than the time taken on the way down to the thrower's hand. Without drag force, the speed of the ball on returning to the thrower's hand is the same as the initial speed when the ball is thrown upwards. With drag force, energy is loss to the environment. Hence the speed on return is less than the speed of throw. Therefore the average speed on the way up is larger than the average speed on the way down. [1] The distance travelled on the way up and down is the same. For the same distance travelled, the time taken is inversely proportional to the average speed. Therefore the time taken on the way up must be smaller because its average speed is larger. [1]	[2]

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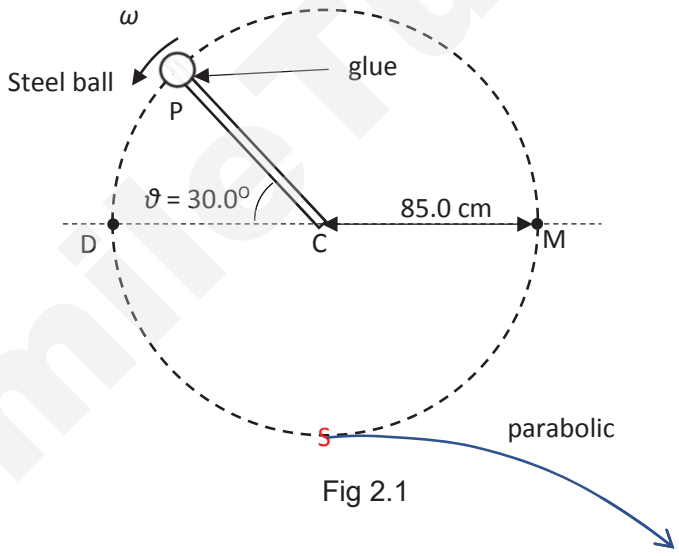
2	a)	(i)	loss in GPE = m g h = m g r sin θ = 0.200 (9.81) 0.850 sin 30.0^{O} [1] = 0.834 J [1]	[2]
		(ii)	As the ball falls, it loses gravitational potential energy. To maintain constant angular velocity and to prevent the kinetic energy from increasing, the work done by the electric motor must be negative [1] to remove the energy from the system.	[1]
		(iii)	Work done = - loss in GPE= - 0.834 J [1]	[1]
	b)	(i)	mark with the letter S on the dotted circle in Fig 2.1 the position of the ball. Sketch the subsequent path taken by the ball after the glue snaps.	
			 Fig 2.1	[2]
			[1] S at the **bottom** [1] path is t**angent to the circle at the start, and curves parabo**lically downwards.	
		(ii)	By Newton's 2nd law, F_{net} on the ball = max glue tension - weight = ma_c $8.50 - 0.200(9.81) = 0.200(0.850)\omega^2$ [1] ω = 6.20 rad s^{-1} [1]	[2]

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	c)	The minimum angular speed is determined by the condition that the ball stays in contact with E at the top, where the net force is the minimum and is only provided by the weight of the ball. $mg = mr\ \omega^2$ $9.81 = 0.85\ \omega^2$ [1] $\omega = 3.40$ rad s-1. [1]	[2]

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3 **(a)** The table below shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B and C.

(i) Explain why the pressure for states A and D are the same. [1]

The pressure in the gas is given by the sum of the atmospheric pressure and the pressure due to the combined weight of the piston, connecting rod and platform. Since these components are the same for both states A and D, the pressure for State D is therefore the same as that for State A.

(ii) Complete the table by filling in the volume for state D. [2]

	Ideal Gas		
State	Pressure (kPa)	Volume (m^3)	Temperature (K)
A	102	1.000	292
B	103	0.990	292
C	103	1.197	353
D	102	**1.209**	353

Table 3.1

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(b)

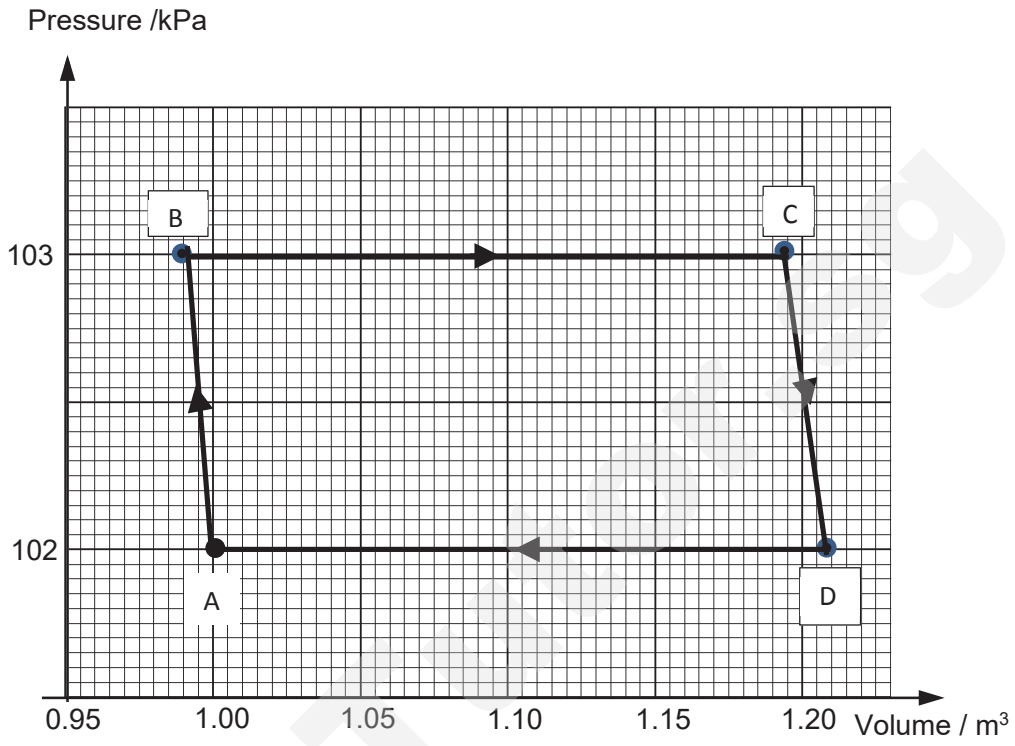

Fig. 3.3

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	(i)	Mark and label state D on Fig. 3.3 and draw the process lines joining state C to state D to state A. State D plotted correctly to accuracy of half the smallest square.	[1]
	(ii)	Hence, using Fig. 3.3, estimate the work done by the ideal gas in one cycle. Workdone is area enclosed by the graph $W = (103000 - 102000)(1.209 - 1.000)$ [1] (Working) $= 209\ J$ [1] (Correct answer) Recognise that the enclosed area is approximately a parallelogram. Alternatively, area can also be obtained by counting of squares. Work Done = 209 J	[2]
	(c)	By considering the kinetic energy of the ideal gas in the metal cylinder, determine the amount of thermal energy, *Q* absorbed by the gas from the heat reservoir as it goes from state B to C. For ideal gas, the internal energy equals its kinetic energy. Internal energy at B, Since $PV = nRT$, the internal energy is $U = \frac{3}{2}nRT = \frac{3}{2}PV$ [1] The change in internal energy from B to C, $\Delta U = \frac{3}{2}\left[\left(103\times10^3\right)(1.197) - \left(103\times10^3\right)(0.990)\right] = 31982\ J$ [1] (find change in U) Based on the First Law of Thermodynamics $Q = \Delta U - W = 31982 - \left[-\left(103\times10^3\right)(1.197 - 0.990)\right]$ [1] (1st Law of Thermodynamics) $= 53303\ J$ [1] (correct answer)	[4]
	(f)	Determine the efficiency of the heat engine. Efficiency $= \frac{\text{Output energy}}{\text{Input energy}} \times 100\%$	[1]

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		$= \frac{209}{32190} \times 100\% = 0.65\%$	

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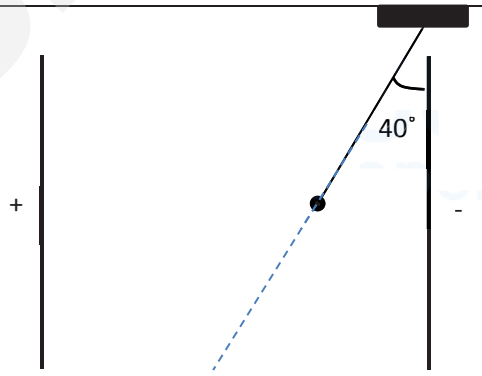
4	**(a)**		Electric field strength at a point is the electric **force per unit positive charge** on a small test charge placed at that point.	[1]
	(b)	**(i)**	Net force in the vertical direction = 0 T cos40° = mg $T = \frac{(0.250)(9.81)}{\cos 40°}$ T = 3.2 N	[1]
		(ii)	1. Net force in the horizontal direction = 0 T sin40° = qE $E = \frac{(3.2)\sin 40°}{12 \times 10^{-3}}$ E = 170 V m^{-1}	[1] [1]
			2. E = ΔV/Δx ΔV = EΔx = 171 × 0.70 sin40° = 77 V	[1] [1]
		(iii)		[1]

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		(iv)	Gain in kinetic energy = loss in gravitational PE + loss in electric PE = mgΔh + qEΔx = (0.250)(9.81)(0.70) + (0.012)(171)(0.70 tan40˚) = 2.9 J	[1] [1] [1]

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5	**(a)**		very high/infinite resistance for negative voltages up to about 0.4 V resistance decreases from 0.4 V	B1 B1
	(b)		initial straight line from (0,0) into curve with decreasing gradient but not to horizontal repeated in negative quadrant	M1 A1
	(c)	**(i)**	R = 122 / 36 = 4.0 Ω or I = P / V = 36 / 12 = 3.0 A and R = 12 / 3.0 = 4.0 Ω	A1
		(ii)	R = V / I = (12 – 0.5 × 2.8) / 2.8 or E = 12 = 2.8 × (R + r) = 3.8 (3.79) Ω or R = 3.8 Ω	C1 A1
		(iii)	Power dissipated across filament lamp = $(2.8)^2$ (3.79) = 29.7 W Power supplied by cell = (2.8)(12) = 33.6 W Percentage of power supplied by cell dissipated across the filament lamp = (29.7 / 33.6) x 100% [1] = 88.4 % [1]	[2]

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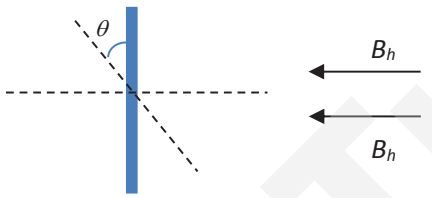
6 a) Faraday's Law of Electromagnetic Induction states that the magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage or the rate of cutting of magnetic flux B2

b) (i) When the coil rotates, the area of the coil that is perpendicular to the horizontal component of the earth's magnetic field (B_h) changes. Thus there is a changing magnetic flux linkage in the coil. B1
By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux linkage will be induced in the coil. B1
OR
As the coil rotates at a constant speed, it cuts the magnetic flux due to the earth's magnetic field. B1
By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux will be induced in the coil. B1

(ii)



Top view of coil

Magnitude of e.m.f. $\varepsilon = d\Phi/dt = d(nB_hA\sin\theta)/dt = d(nB_hA\sin\omega t)/dt = \omega nB_hA\cos\omega t$
Since Φ is sinusoidal, ε is also sinusoidal
M1 A1

(iii) $\omega = v/r = 200 \times 10^3/(3600)(0.250) = 222.2$ rad s^{-1} A1

(iv) $\varepsilon_{max} = n\omega AB_h$ B1

(v) $n = \varepsilon_{max}/\omega AB_h = 15 \times 10^{-3}/222.2 \times 10^{-2} \times 1.5 \times 10^{-5} = 450$ turns A1

(vi) The rod which holds the cups is rotating at right angles to the vertical component of the Earth's magnetic field, and therefore is acting as a crude form of spinning Faraday's disk. The e.m.f. is established between the centre and either ends of the rod, hence there will be no potential difference across the two ends of each metal rod during rotation at maximum speed.

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Section B

7	**(a)**	**(i)**	$f = 1/T = 1/0.50 = 2.0$ Hz	A1
		(ii)	$a = -\omega^2 x \rightarrow \omega^2 = \left(\frac{\rho A g}{m}\right)$ $\rightarrow 4\pi^2 f^2 = \left(\frac{\rho A g}{m}\right) \rightarrow \rho = \frac{4\pi^2 f^2 m}{Ag}$ $\rho = \frac{4\pi^2 (2.0)^2 0.032}{4.2\times10^{-4}(9.81)} = 1226 \text{ kg m}^{-3}$	M1 M1 A1
		(iii)	The energy of the oscillations is given by $\frac{1}{2}m\omega^2 x^2$, where x is the displacement from the equilibrium point. $E_{t=0} = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}0.032(4\pi^2 2.0^2)(-1.5)^2 = 5.68\times10^{-4}$ J $E_{t=1.50\text{ s}} = \frac{1}{2}m\omega^2 x_{1.50}^2 = \frac{1}{2}0.032(4\pi^2 2.0^2)(-0.65)^2 = 1.07\times10^{-4}$ J % loss $= \frac{5.68\times10^{-4}\text{ J} - 1.07\times10^{-4}\text{ J}}{5.68\times10^{-4}\text{ J}} = 81\%$ loss	M1 M1 A1
		(iv)	As the liquid is more viscous, <u>greater damping forces</u> will act on the tube. <u>More negative work done</u> by the tube against these forces per oscillation. Hence, the tube oscillates with much <u>less energy</u> in this liquid. Energy is directly proportional to the square of the amplitude. Therefore, the tube oscillates at smaller amplitudes.	M1 M1 A0
	(b)	**(i)**	The amplitude of vibration is **the same at all points in a travelling** (progressive) wave but it **varies with position in a stationary wave**, from **zero at nodes to maximum at antinodes**. The energy is **being transmitted in a travelling wave** however it is stored/**not transmitted in a stationary wave**.	M1 M1 M1
		(ii)	Shape X: Sine wave with less amplitude Shape Y: Horizontal line Shape Z: Negative sine wave with less amplitude	M1 M1 M1
	(c)	**(i)**	5 fringe separations = 10.4 mm $\Delta y = \frac{\lambda L}{d}$	M1

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			$\frac{10.4 \times 10^{-3}}{5} = \frac{633 \times 10^{-9}(2.95)}{d}$ $d = 8.98 \times 10^{-4}$ m = 0.898 mm	M1
		(ii)	Any of 3 below: • Greater angle for bright spots (principal maxima) • Less number of bright spots • Greater intensity at bright spots • Greater distance between subsequent bright spots	M1 M1 M1

8	**(a)**	**(i)**	$^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e} + \gamma$ [B1] for e. [B1] for the other 2.	[2]
		(ii)	Number of nuclei in 1 g of C0-60 $= \frac{1}{60} \times 6.02 \times 10^{23}$ [M1] $= 1.003 \times 10^{22}$	[1]
		(iii)	$A = \lambda N$ $= \frac{\ln 2}{5.272 \times 265 \times 24 \times 60 \times 60} 1.003 \times 10^{22}$ [M1] $= 4.182 \times 10^{13}$ Bq radiation power $= (4.182 \times 10^{13}) \times 2.8$ $= 1.171 \times 10^{20}$ eV $= 18.7$ W [A1]	[2]
	(b)	**(i)**	A packet of **electromagnetic radiation energy of** [1] **energy > 100 keV OR wavelength < 10 pm.** [1]	[2]
		(ii)	<u>Method 1</u> $E = \frac{hc}{\lambda}$ $(1.3 \times 10^{6})(1.60 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{\lambda}$ [M1] $\lambda = 9.5625 \times 10^{-13}$ m	[2]

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$$p = \frac{h}{\lambda} = \frac{(6.63\times10^{-34})}{9.5625\times10^{-13}} = 6.93\times10^{-22} \text{ kg m s}^{-1} \quad [A1]$$

Method 2

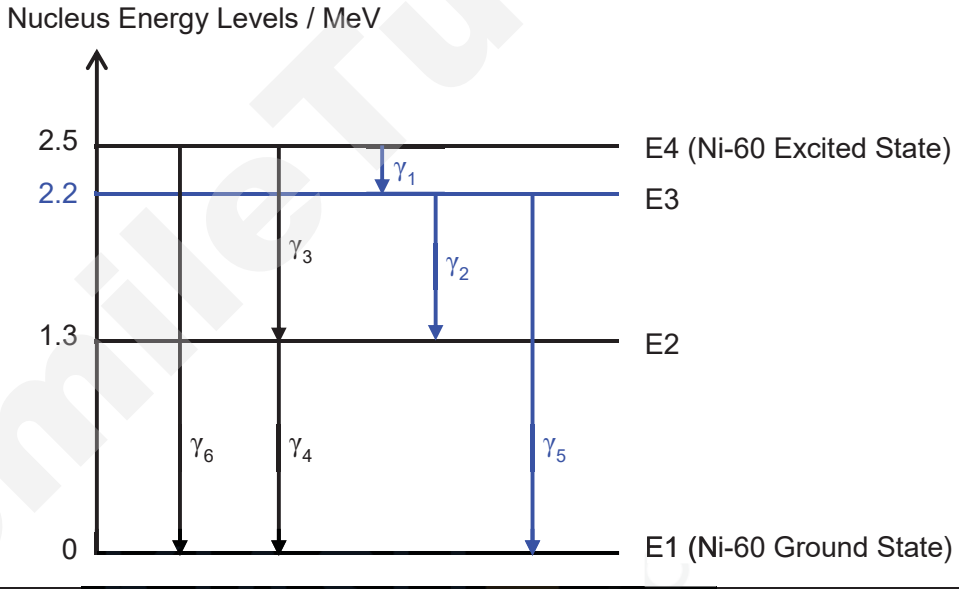
From $\lambda = \frac{h}{p}$ and $E = \frac{hc}{\lambda}$, we obtain $E = pc$

$$p = \frac{E}{c} = \frac{(1.3\times10^{6})(1.60\times10^{-19})}{3.00\times10^{8}}$$
$$= 6.93\times10^{-22} \text{ kg m s}^{-1}$$

(iii) When the nucleus de-excites from a higher to lower energy level, a gamma photon of energy equal to the energy transition is emitted. [B1]
Since the energy levels of the nucleus is discrete, the emission spectrum is a **line spectrum** [B1] [2]

(iv)

1.



[2]

2.

$$\Delta E = \Delta m.c^2$$
$$(2.5\times10^{-6})(1.60\times10^{-19}) = \Delta m.(3.00\times10^{8})^2 \quad [M1]$$
$$\Delta m = 4.444\times10^{-30} \text{ kg}$$
$$= 0.0002677 \text{ u}$$

At excited state
$$m = 59.93079 + 0.0002677 = 59.93347u \quad [A1]$$

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			By the mass-energy equivalence principle, the mass of the excited nucleus has more energy and therefore larger mass than the nucleus in its ground state. [B1]	[3]
	(c)	**(i)**	Energy of beta-particle $= 2.8 - 2.5 = 0.3$ MeV [M1] $\frac{hc}{\lambda_{min}} = E_\beta$ $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda_{min}} = (0.3\times10^{-6})(1.6\times10^{-19})$ $\lambda_{min} = 4.14\times10^{-12}$ m [A1]	[2]
		(ii)	Beta-particles knock the innermost shell electrons out of the lead atoms, creating vacancies in the innermost shell. [B1] When electrons from higher shells cascade down to fill the vacancy, X-ray photons with energy corresponding to the energy transitions are emitted. [B1]	[2]

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H2 Physics 9749
2017 C2 Prelim Exam
Paper 4 (Practical)
Suggested Mark Schemes

These mark schemes are published to serve as a guideline to teachers and students, to indicate the requirements of the test. They show the basis on which the marks are awarded, however it is expected that alternative correct answers and unexpected approaches will sometimes be encountered. **Due credit will be given at the discretion of the teachers** provided the students have shown understanding of the concepts tested. In the same vein, **students who arrived at the correct answer or provided a correct statement but otherwise in their working contradicted themselves or showed that they did not really understand the concept will/may not be credited**.

Mark schemes must be read in conjunction with the question. HCI will not enter into discussions or correspondence in connection with these mark schemes.

About H2 Physics 9749 Paper 4 (SEAB Assessment Syllabus Document)

Paper 4 is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal practical assessment.

Candidates will be assessed in the following skill areas:

(a) **Planning (P)**

Candidates should be able to:

- define a question/problem using appropriate knowledge and understanding
- give a clear logical account of the experimental procedure to be followed
- describe how the data should be used in order to reach a conclusion
- assess the risks of the experiment and describe precautions that should be taken to keep risks to a minimum.

(b) **Manipulation, measurement and observation (MMO)**

Candidates should be able to:

- demonstrate a high level of manipulative skills in all aspects of practical activity
- make and record accurate observations with good details and measurements to an appropriate degree of precision
- make appropriate decisions about measurements or observations
- recognise anomalous observations and / or measurements (where appropriate) with reasons indicated.

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(c) **Presentation of data and observations (PDO)**

Candidates should be able to:

- present all information in an appropriate form
- manipulate measurements effectively in order to identify trends / patterns
- present all quantitative data to an appropriate number of decimal places / significant figures.

(d) **Analysis, conclusions and evaluation (ACE)**

Candidates should be able to:

- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from the interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors, limitations of measurements and / or experimental procedures used, explaining how they affect the final result(s)
- state and explain how significant errors / limitations may be overcome or reduced, as appropriate, including how experimental procedures may be improved.

The assessment of skill area P will be set in the context of the content syllabus, requiring candidates to apply and integrate knowledge and understanding from different sections of the syllabus. It may also require treatment of given experimental data to draw a relevant conclusion and in the analysis of a proposed plan.

The assessment of skill areas MMO, PDO and ACE will be set in the context of the syllabus. The assessment of PDO and ACE may also include questions on data analysis which do not require practical equipment and apparatus.

Candidates are not allowed to refer to notebooks, textbooks or any other information in the Practical examination.

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Suggested Mark Schemes and Markers' Comments

Qn 1 Mark Scheme and Markers' Comments

Question	Answer	Marks
1(a)(i)	**PDO** Repeat measurements of *x* and find average. **MMO** Value of *x* to the appropriate precision (i.e. 2 d.p. in cm) with unit.	**1** **1**
1(a)(ii)	**ACE** Percentage uncertainty in *x* calculated correctly using sensible value of Δx (absolute uncertainty of *x*) (accepted range of Δx is 0.5 mm to 2.0 mm) to indicate unevenness of surface rather than precision of vernier caliper.	**1**
1(b)(i)	**MMO** Value of *d* to the nearest 0.1 mm with unit. (accepted range of small hole is between 0.50 cm and 0.80 cm)	**1**
1(b)(ii)	**ACE** Calculation of *A* in suitable units with same or one more significant figure than *d*.	**1**
1(c)(v)	**ACE** Estimation of m using ratio of *x* values and 100 g with unit.	**1**
1(d)	**ACE** Correct calculation of time taken for 5 g with unit.	**1**
1(e)	**MMO** Measurement of *d* for big hole. (accepted range of big hole is between 0.70 cm and 1.00 cm) **ACE** Calculation of *A*. **PDO** Values of *d* to appropriate precision and *A* to appropriate number of significant figures with units. **PDO** Flow rate *R* with appropriate units, e.g. g s^{-1}. **ACE** Determination of constant of proportionality. (i.e $k = R / A$) **ACE** Draw conclusion based on stated criterion e.g. not obeyed because more than 20% difference in values of *k*.	**6**

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1(f)	**ACE** Investigate flow of pepper with hole size. Use smaller holes. Investigate flow of pepper with number of holes. Use more than one hole of this size.	**2**
	Total	**15**

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Qn 2 Mark Scheme and Markers' Comments

Question	Answer	Marks
2(a)(ii)	**MMO** Value of y_0 to the appropriate precision with unit.	**1**
2(a)(vi)	**ACE** Calculation of $(y - y_0)$ in suitable units to an appropriate decimal place (maintain same d.p. as y_0 and y).	**1**
2(a)(vii)	**ACE** Percentage uncertainty in $(y - y_0)$ calculated correctly using sensible value of $\Delta(y - y_0)$ (absolute uncertainty of $y - y_0$). (accepted range of $\Delta(y - y_0)$ is 2 mm to 6 mm)	**1**
2(c)(i)	**MMO** y_0 and y for both masses on Ruler A **ACE** Calculation of $(y - y_0)$ and percentage change of $(y-y_0)$. **PDO** Values of y_0 to appropriate precision and $(y - y_0)$ to appropriate number of decimal places with units.	**2**
2(c)(ii)	**ACE** Draw conclusion based on comparison of the percentage change and percentage uncertainty.	**1**
2d(i)	**ACE** Relevant points (with appropriate elaboration) might include: • difficulty in judging whether metre rule B, that is clamped, is vertical • uncertainty in reading y and y_0 due to the thickness of rule or parallax error as rule B is a small distance from rule A.	**1**
2d(ii)	**ACE** Relevant points (with appropriate elaboration) might include: • use spirit level to check that metre rule B is vertical. • attach needle as a pointer at the end of rule A.	**1**
	Total	**8**

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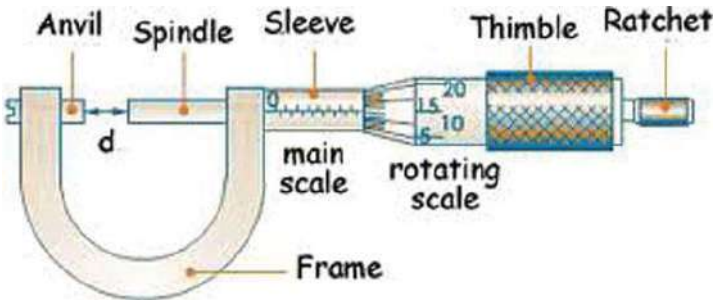
Qn 3 Mark Scheme and Markers' Comments

The beginning parts

3ai
Value for d in the range 0.17 mm ≤ d ≤ 0.21 mm, with **unit**.
Accept: 0.00019 m, 0.019 cm
Reject: 0.190 mm



3cii
Value for V_1 range 0.300 V ≤ V_1 ≤ 0.600 V
Value for V_2 range 0.200 V ≤ V_2 ≤ 0.400 V
V_1 larger than V_2 by 0.1 V

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Tabulation

3d

Data (2 marks)
Deduct 1 mark if only 5 sets **tabulated**.
Deduct 2 mark if 4 or less sets tabulated.
Deduct 1 mark per column of nonsensical data collected.
Deduct 1 marks if minor assistance rendered.
Deduct 2 marks if major assistance rendered.

Heading (1 mark)
Units must be presented.
Penalise broken table

Range of IV (1 mark)
$\Delta l \geq 25$ cm.

Decimal Place (1 mark)
l to nearest 1 mm
V_1 and V_2 to the nearest 0.001 V.

Significant Figure (1 mark)
V_1/V_2, the number of s.f. should be correct.

Calculation (1 mark)
All V_1/V_2 calculated correctly.
Penalise rounding off error.

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Graph

3e

Scale
Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
Scales must be chosen so that plotted points occupy at least half the graph grid in both *x* and *y* directions.
Axes must be labelled (with units if any).

Plots
All observations must be plotted to an accuracy of half a small square or less.
Penalise student who used x to mark a grad point.

BFL
There must be a fair scatter of points either side of the line.
Penalise student who identified anomalous point(s) wrongly.
Student must have at least 5 non-anomalous data points to be awarded the BFL mark.
The data points show no trend at all, the BFL mark is forfeited.

Linearising equation.
Gradient
Gradient – the hypotenuse must be greater than half the length of the drawn line. Read-offs must be accurate to within half a small square.

y-intercept
y-intercept is calculated from $y = mx + c$ **using a point on the line**.
Or
y-intercept must be read off to the nearest half small square **accuracy**

P and Q
Values of *P* and *Q* calculated correctly with **units**.

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The ending parts

3f

There is no anomalous data as no data point deviates substantially from the linear trend set by the other data points. All data points are closely and evenly scattered **about** the best fit line.

Or

(X,Y) is a anomalous point because it deviates significantly from the linear trend set by the other data points.

3g

Working (substitution) must be presented.

ρ in range 3×10^{-7} to $7\times10^{-7}\,\Omega$ m. (4.9×10^{-7} is the theoretical answer)

.

3hi

Sources of errors:

1. Uncertainty in determining the position of L and M | Uncertainty in measurement of l because of considerable **thickness** of crocodile clips.

3hii

Improvements

1. replace the crocodile clips with jockeys

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Qn 4 Mark Scheme and Markers' Comments

Suggested Mark Scheme for Q4 Planning Question:

	Marks	Marking Points
Diagram	3	• Strain gauge stuck in correct orientation to cylinder (can be credited in procedure) • Cylinder with mass on top and resting on platform/table-top and not floating. • Electrical circuit correctly drawn.
Variables	4	**V1.** How to vary compression 10 times (load different masses) **V2.** How to measure the mass and calculate force (ΔF = mg) (or use force meter) **V3.** How to measure resistance **V4.** How to measure ΔR (before and after loading)
Analysis	1	**A1.** What graph to plot and how to obtain n
Reliability	3	Any good further design details, some of these might be: **R1, R2 and R3** • **Control!** Keep temperature constant, monitor with a thermometer • **Preliminary experiments** to determine suitable range of masses to obtain observable/meaningful results • Way to apply compressive force uniformly over the cross-section of cylinder • Repeat measurement of mass/ resistance and take average to reduce random error. • After each unloading, check that the resistance value returns to the original value, otherwise some permanent deformation might have taken place and the load might have been excessive for the experiment
Safety	1	Any relevant safety precaution **S1** e.g.: • Wear goggles in case concrete cracks • Reasonable measure to prevent cylinder/ heavy masses from toppling • Wear gloves to prevent getting burnt by hot wires (for those using power source)
Total	12	

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Analysing the Question

Back ground info

4 Concrete is widely used for construction and its manufacture contributes 5% to the world's carbon dioxide (CO_2) production. One way of reducing the amount of CO_2 produced could be to use less cement in the production of concrete.

A company is producing concrete with low cement content and wishes to see how the material behaves under a compressive force. A compressive force applied to a concrete object will reduce the length of the object in the direction of the force very slightly.

The reduction in length of the object is to be measured using a strain gauge.

When a wire has its length changed, its resistance changes. A strain gauge consists of a length of thin wire as shown in Fig. 4.1.

Intro to new instrument. Read carefully!

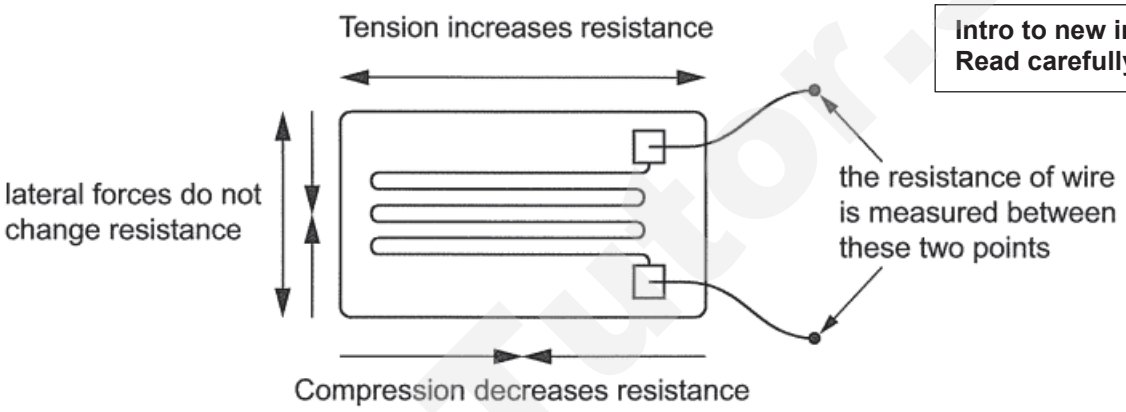

Fig. 4.1

The gauge consists of a wire wound backwards and forwards and embedded in thin plastic. The plastic is then bonded firmly to the specimen being investigated.

The relation between change in resistance ΔR and change in force ΔF is

Need to define ΔR and ΔF

$$\Delta R = k\,(\Delta F)^n$$

Relation given, no need to hypothesize

where k and n are constants.

You are provided with some heavy masses, a low voltage power supply and other equipment usually found in a Physics laboratory.

Can't assume normal slotted mass! **Safe, won't get electrocuted!**

Design an experiment to determine the value of n for compressive forces applied to a small concrete cylinder along its axis.

TASK OBJECTIVE!!

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the compressive force and change in resistance are measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Important hints!

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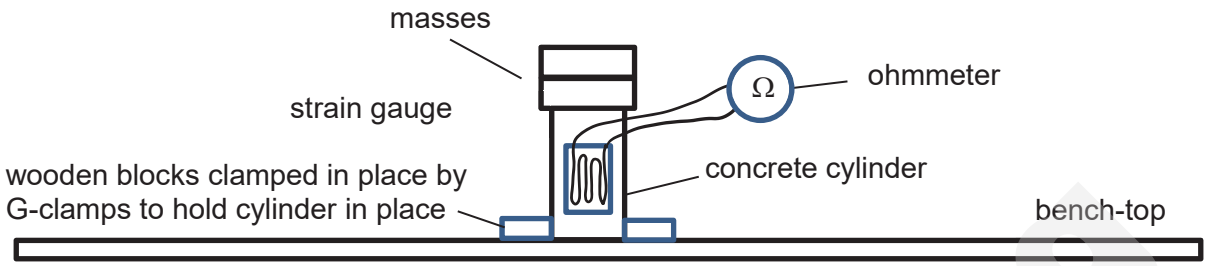
Diagram



1. Set up the apparatus as shown. Adhere the strain gauge to the cylinder using in the orientation shown.
2. Conduct the experiment in a temperature controlled room. Monitor temperature with a thermometer.
3. Before loading the cylinder, measure the resistance R_1 using an ohmmeter.
4. Load the cylinder evenly across its cross section by placing the mass centrally on the cylinder.
5. Calculate the compressive force using $\Delta F = mg$, where m is measured with an electronic mass balance.
6. Measure the new resistance R_2, and calculate $\Delta R = R_2 - R_1$
7. **Repeat steps 3 to 6** until a total of **10 sets of data** have been collected.
8. $\Delta R = k\,(\Delta F)^n$
   $\lg \Delta R = \lg k + n \lg (\Delta F)$

   Plot lg ΔF against lg ΔR to obtain a straight line and determine the gradient of the line which is the numerical value for n.

Additional details

1. Conduct preliminary experiments to determine suitable range of masses to obtain observable differences.
2. After each unloading, check that the resistance returns to its original value. Otherwise the load might have been too much, and has caused permanent deformation.
3. Repeat for each load, average the readings to check for reproducibility/reduce random error.

Safety

1. Wear safety goggles to protect eyes in case concrete cracks and fragments flies off as projectiles.
2. Wedge the cylinder lightly on opposite sides using G-clamps to secure it and prevent possible toppling.

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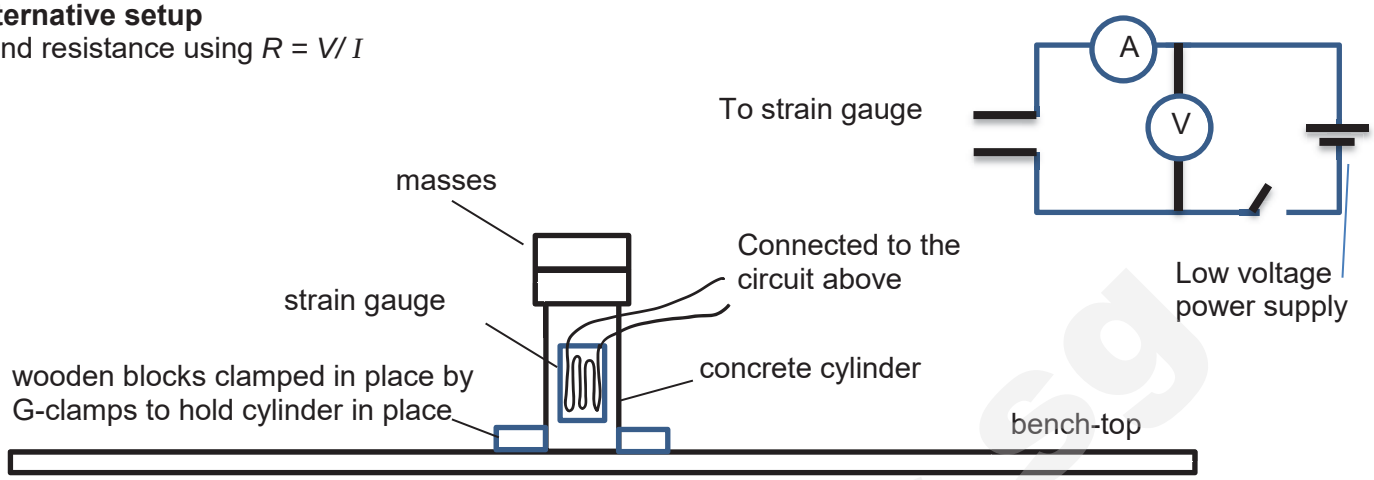
Alternative setup
*Find resistance using $R = V/I$



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CLASS		INDEX NUMBER	

PHYSICS 9749/01

Paper 1 Multiple Choice **15 September 2017**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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This document consists of **19** printed pages and **1** blank page

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Data

speed of light in free space	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	$= 1.60 \times 10^{-19}$ C
the Planck constant	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	g	$= 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\Phi = -\frac{GM}{r}$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{\left(x_o^2 - x^2\right)}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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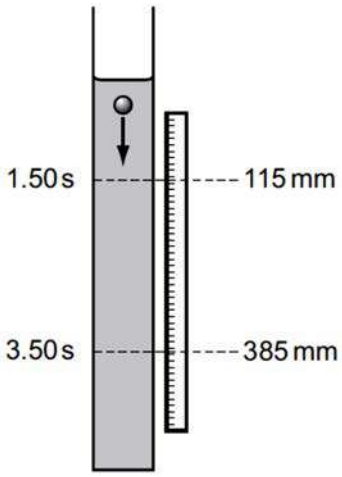
1 The diagram shows an experiment to measure the speed of a small ball falling at constant speed through a clear liquid in a glass tube.



There are two marks on the tube. The top mark is positioned at (115 ± 1) mm on the adjacent rule and the lower mark at (385 ± 1) mm. The ball passes the top mark at (1.50 ± 0.02) s and passes the lower mark at (3.50 ± 0.02) s.

The constant speed of the ball is calculated by $\frac{385\text{-}115}{3.50\text{-}1.50} = \frac{270}{2.00} = 135 \text{ mm s}^{-1}$.

Which expression calculates the fractional uncertainty in the value of this speed?

A $\frac{2}{270} + \frac{0.04}{2.00}$

B $\frac{2}{270} - \frac{0.04}{2.00}$

C $\frac{1}{270} \times \frac{0.02}{2.00}$

D $\frac{1}{270} \div \frac{0.02}{2.00}$

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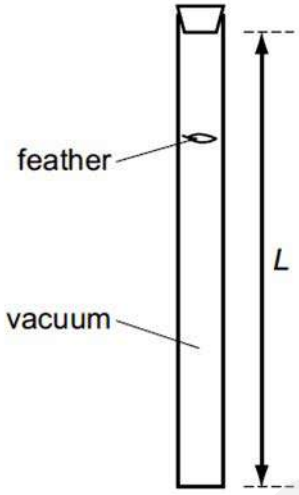
2 The diagram shows a laboratory experiment in which a feather falls from rest in a long evacuated vertical tube of length *L*.



The feather takes time *t* to fall from the top to the bottom of the tube.

How far will the feather have fallen from the top of the tube in time 0.50 *t*?

A 0.13 *L* **B** 0.25 *L* **C** 0.38 *L* **D** 0.50 *L*

3 A man applies a horizontal force to a supermarket trolley and the trolley accelerates uniformly in the direction of the force.

Which statement is correct?

A The force applied by the man on the trolley is greater than the force applied by the trolley on the man.

B The force applied by the man on the trolley equals the force applied by the trolley on the man.

C The forces acting on the trolley are in equilibrium.

D The total frictional force acting on the trolley equals the force applied by the man on the trolley.

4 A block of ice of density 0.9 g cm^{-3} is held below the surface of water, density 1.0 g cm^{-3}. The block of ice is then released and floats to the surface.

What is the ratio $\frac{\text{upthrust when fully submerged}}{\text{upthrust when floating}}$?

A 0.1 **B** 0.9 **C** 1.0 **D** 1.1

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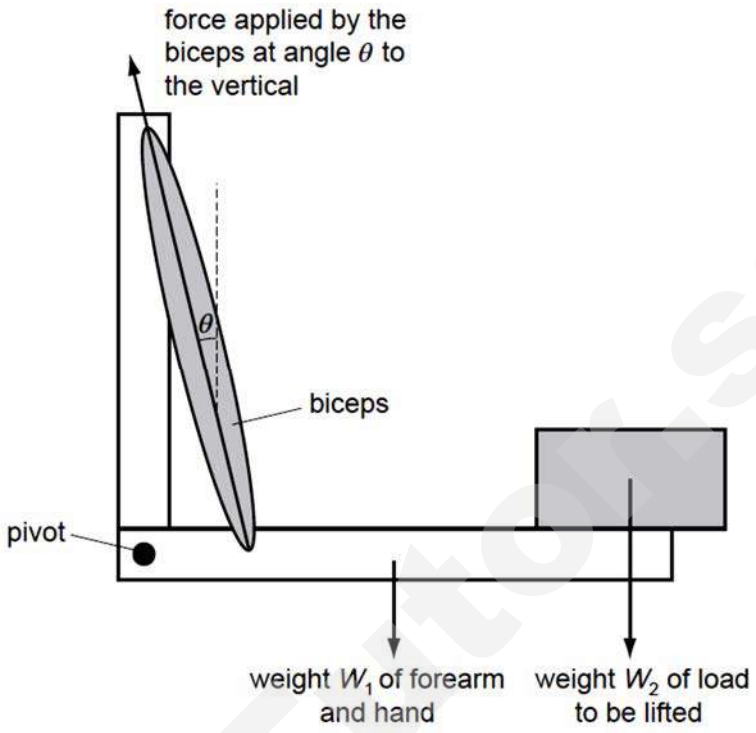
5 The diagram shows a model of an arm. A force applied by the biceps muscle can hold the arm in equilibrium while it supports a load.



Which statement is correct when the arm is in equilibrium in the position shown?

A The force at the pivot is zero.

B The force from the biceps is bigger when the load is moved nearer to the pivot.

C The force from the biceps is equal to $W_1 + W_2$.

D The resultant force on the biceps is zero.

6 A hydroelectric power station uses the gravitational potential energy of water to generate electrical energy.

In one particular power station, the mass of water flowing per unit time is 1.5×10^5 kg s^{-1}. The water falls through a height of 120 m.

The electrical power generated is 100 MW.

What is the efficiency of the power station?

A 5.6% **B** 43% **C** 57% **D** 68%

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7 A ball of mass 0.30 kg is attached to a string and moves in a vertical circle of radius 0.60 m at a constant speed of 5.0 m s^{-1}.

Which line, **A** to **D**, in the table gives the correct values of the minimum and maximum tension in the string?

	Minimum tension / N	Maximum tension / N
A	2.5	5.4
B	6.7	9.6
C	13	13
D	9.6	15

8 A particle of mass *m* moves with constant speed *v* in a circle of radius *r*. The work done on the particle by the centripetal force in one complete revolution is

A $2\pi mv$ **B** $\frac{2\pi v^2}{m}$ **C** $\frac{2\pi m}{v^2}$ **D** zero

9 Which one of the following statements is true when an object performs simple harmonic motion about a central point?

A The acceleration is always directed away from the central point.

B The acceleration and velocity are always 180° out of phase.

C The velocity and displacement are always in the same direction.

D The acceleration and displacement are always 180° out of phase.

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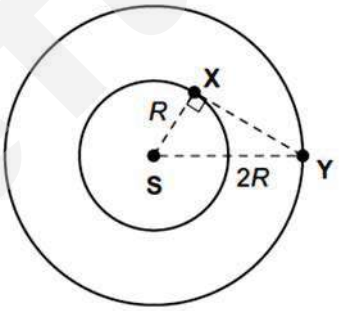
10 A body executes simple harmonic motion of amplitude 100 mm along a line **PQ** centred on **O**. When passing through **O** the body has 50 J of kinetic energy.

When it is at a point 40 mm from **O**, which row gives the correct values of E_k and E_p?

	E_k / J	E_p / J
A	42	8
B	30	20
C	20	30
D	18	32

11 Two planets X and Y are in concentric circular orbits about a star S. The radius of the orbit of X is R and the radius of orbit of Y is $2R$.



The gravitational force between X and Y is F when angle SXY is 90°, as shown in the diagram.

What is the gravitational force between X and Y when they are nearest to each other?

A $2F$ **B** $3F$ **C** $4F$ **D** $5F$

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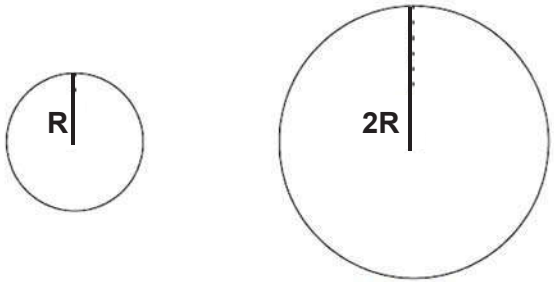
12 The diagram shows two planets X and Y.



Planet X Planet Y

Planet X and planet Y have the same mean density.

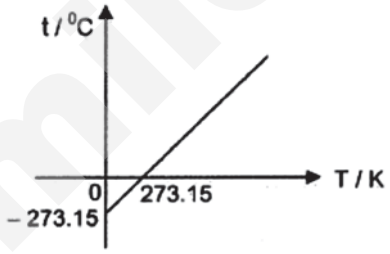
The radius of planet X is half that of planet Y.

The ratio $\frac{\text{gravitational field at the surface of planet X}}{\text{gravitational field at the surface of planet Y}}$ is

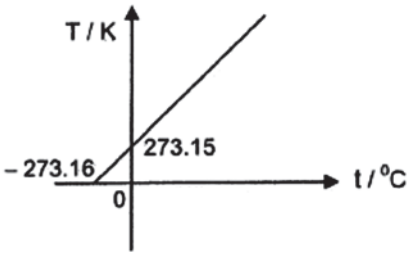
A $2\sqrt{2}$ **B** 2 **C** $\sqrt{2}$ **D** $\frac{1}{2}$

13 Which of the following graphs best shows the correct relationship between the thermodynamic temperature (K) and the Celsius temperature (°C)?

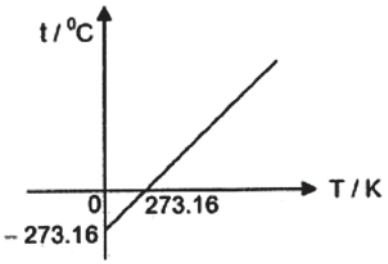
A



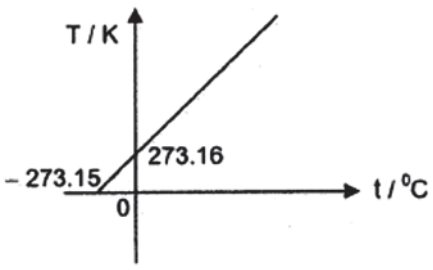
B



C



D



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14 Which statement about internal energy is correct?

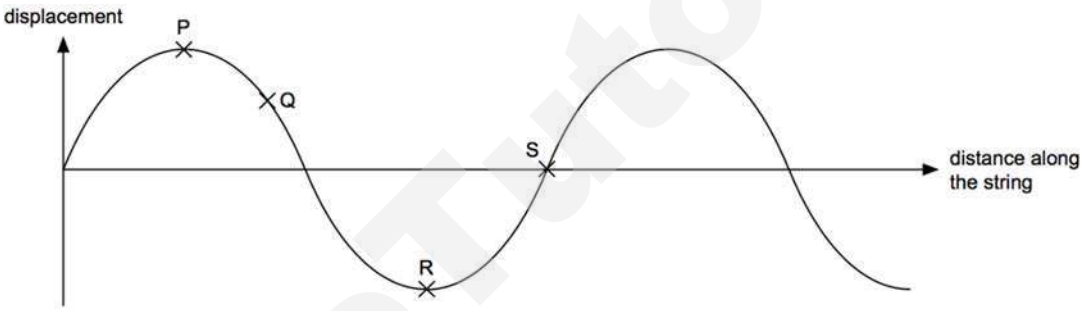
A The internal energy of a system can be increased without transfer of energy by heating.

B The internal energy of a system depends only on its temperature.

C When the internal energy of a system is increased, its temperature always rises.

D When two systems have the same internal energy, they must be at the same temperature.

15 The figure shows the shape at a particular instant of part of a transverse wave travelling from left to right along a string.



Which statement about the motion of elements of the string at this instant is correct?

A The speed of Q is higher than S.

B Both Q and S are moving upwards.

C The energy of P and S is entirely kinetic.

D The acceleration of P and R is a maximum.

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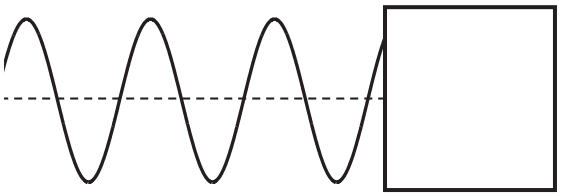
16 A progressive wave travelling to the right hits a solid surface and gets reflected after experiencing a phase change of π rad. The figure below shows the incident wave at a particular instant of time.

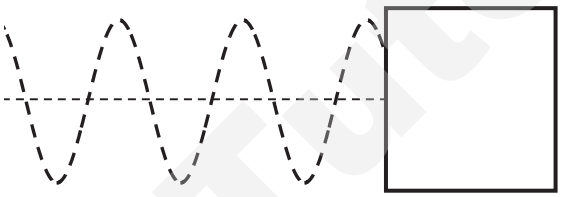


Which of the following shows the corresponding *reflected* wave?

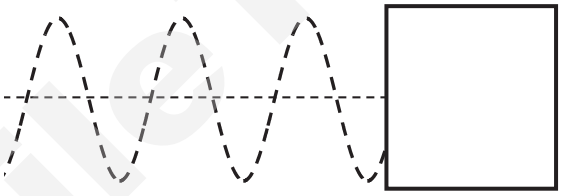
A



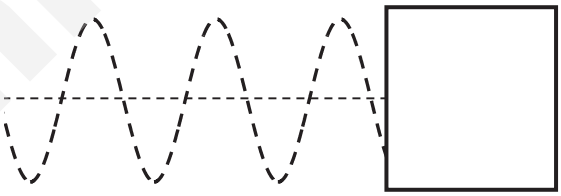
B



C



D



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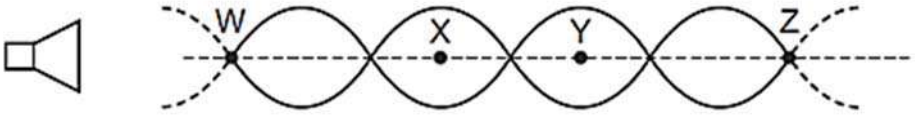
17 The diagram represents a stationary wave formed by the superposition of sound waves from a loudspeaker and their reflection from a metal sheet (not shown).



W, X, Y and Z are four points on the line through the centre of this wave.

Which statement about this stationary wave is correct?

A A displacement antinode is formed at the surface of the metal sheet.

B A node is a quarter of a wavelength from an adjacent antinode.

C The oscillations at X are in phase with those at Y.

D The particles of the waves oscillate at right angles to the line WZ.

18 The interference patterns from a diffraction grating and a double slit are compared.

Using the diffraction grating, yellow light of the first order is seen at 30° to the normal to the grating. The same light produces interference fringes on a screen 1.0 m from the double slit. The slit separation is 500 times greater than the line spacing of the grating.

What is the fringe separation on the screen?

A 2.5×10^{-7} m **B** 1.0×10^{-5} m **C** 1.0×10^{-3} m **D** 1.0×10^{-1} m

19 Each of the nuclei from the four options is accelerated from rest through the same potential difference.

Which one completes the acceleration with the **lowest** speed?

A $^{1}_{1}H$ **B** $^{4}_{2}He$ **C** $^{7}_{3}Li$ **D** $^{9}_{4}Be$

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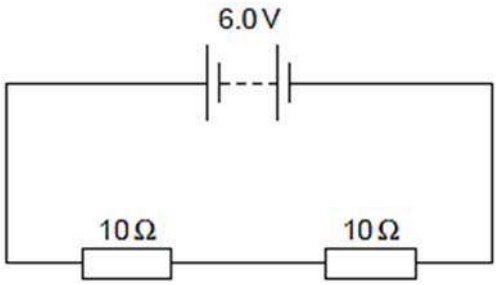
20 A battery of negligible internal resistance is connected to two 10 Ω resistors in series.



What charge flows through each of the 10 Ω resistors in 1 minute?

A 0.30 C **B** 0.60 C **C** 3.0 C **D** 18 C

21 When a battery is connected to a resistor, the battery gradually becomes warm. This causes the internal resistance of the battery to increase whilst its e.m.f. stays unchanged.

As the internal resistance of the battery increases, how do the terminal potential difference and the output power change, if at all?

	terminal potential difference	output power
A	decrease	decrease
B	decrease	unchanged
C	unchanged	decrease
D	unchanged	unchanged

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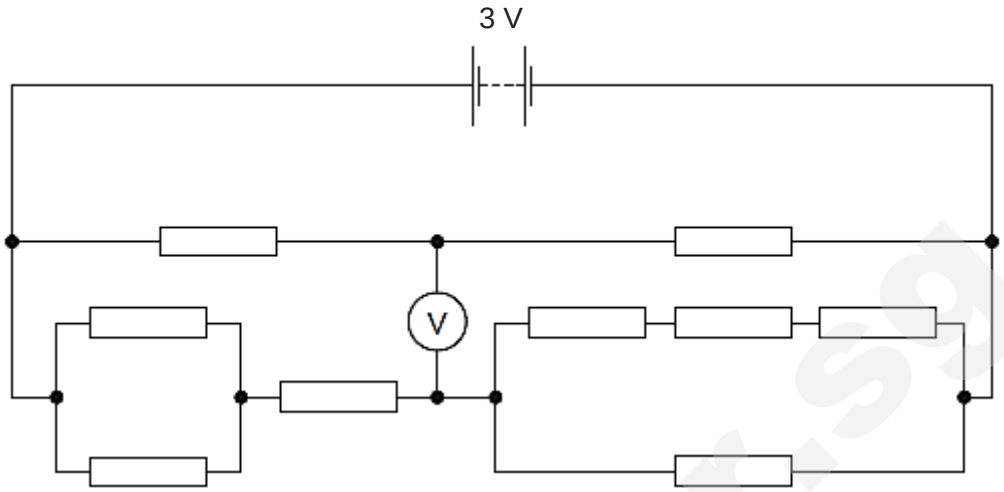
22 A circuit is set up as shown, supplied by a 3 V battery. All resistances are 1 kΩ.



What will be the reading on the voltmeter?

A 0 **B** 0.5 V **C** 1.0 V **D** 1.5 V

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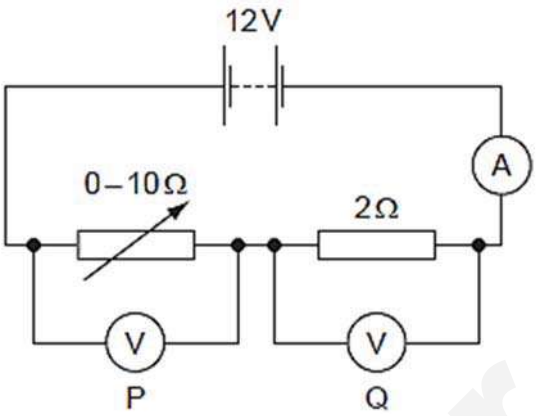
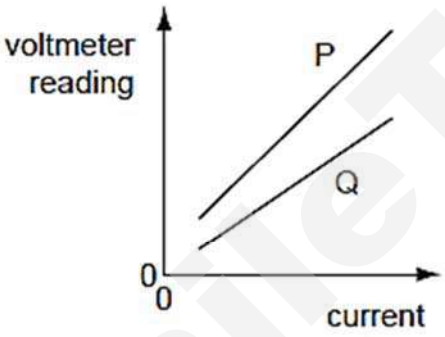
23 A 12 V battery is in series with an ammeter, a 2 Ω fixed resistor and a 0 – 10 Ω variable resistor. High-resistance voltmeters P and Q are connected across the variable resistor and the fixed resistor respectively, as shown.



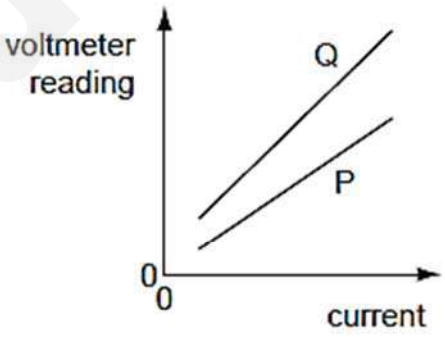
The resistance of the variable resistor is changed from its maximum value to zero.

Which graph shows the variation with current of the voltmeter readings?

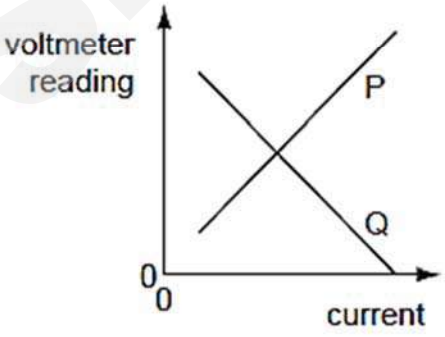
A



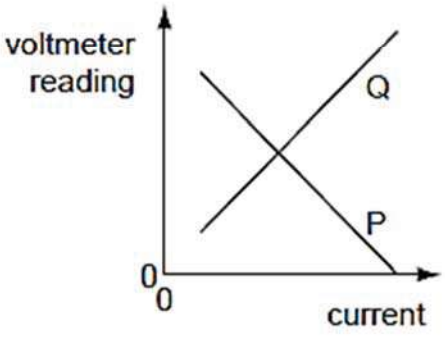
B



C



D



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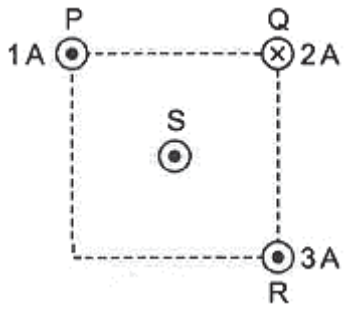
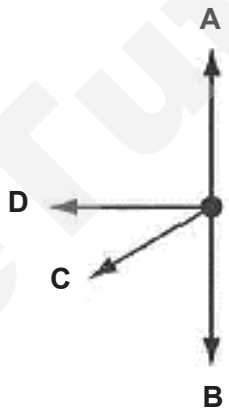
24 The diagram shows a horizontal plane through which four long straight vertical wires pass.



Wires P, Q and R are at three corners of a square and wire S is at the centre.

Wire P carries a current of 1 A out of the paper. Wire Q carries 2 A into the paper. Wire R carries 3 A out of the paper. Wire S carries a current out of the paper.

What is the direction of the resultant force acting on wire S?



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25 A beam of electrons is directed into a magnetic field and is deflected by it.

Diagram 1 represents a magnetic field in the plane of the paper.
Diagram 2 represents a magnetic field directed perpendicular into the plane of the paper.

The lines **A**, **B**, **C** and **D** represent possible paths of the electron beam. All paths are in the plane of the paper.

Which line best represents the path of electrons inside the field?

Diagram 1

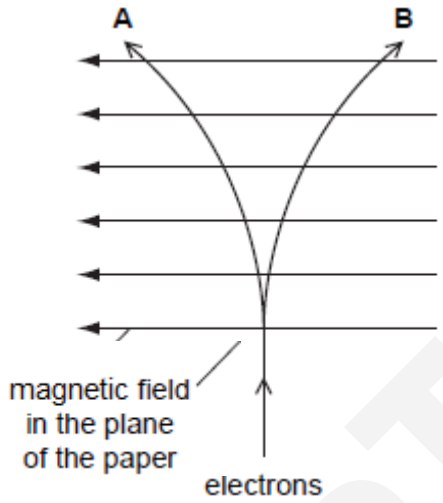
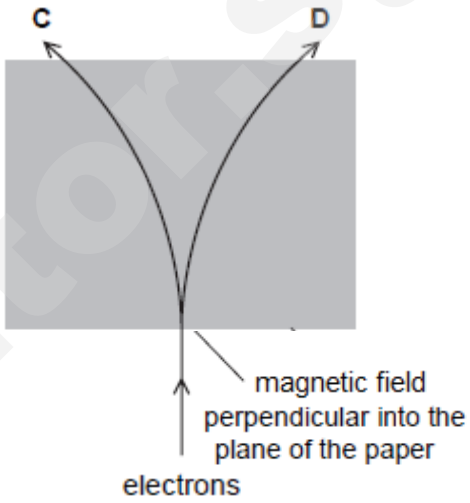


Diagram 2



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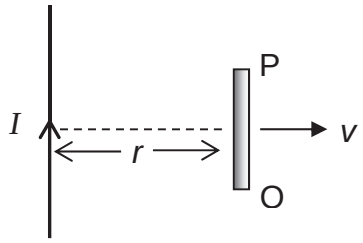
26 The diagram below shows a long wire carrying a current I.

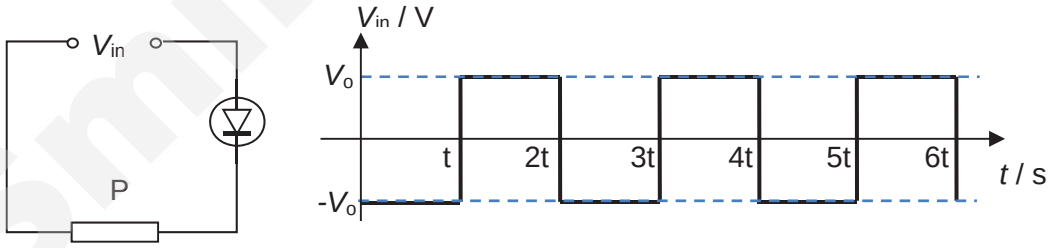
A straight conductor PQ is placed on the same vertical plane as the wire and is moved at constant speed v away from the wire.



How will the magnitude of the induced e.m.f. in PQ vary and which end will be at a higher potential?

	magnitude of induced e.m.f.	end at higher potential
A	decreases	P
B	decreases	Q
C	increases	P
D	increases	Q

27 A rectifier is connected in series with load P and an alternating voltage supply as shown in the figure.



What is the value of the r.m.s. voltage across load P?

A 0.18 V_o **B** 0.50 V_o **C** 0.71 V_o **D** 1.0 V_o

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28 The work function of platinum is twice that of calcium. If the *minimum* photon energy required to emit photoelectrons from the surface of platinum is *E*, then that for the surface of calcium would be

A 2*E*

B 3*E*/2

C *E*/2

D *E*/4

29 In a X-ray tube, electrons of high energy *E* are incident on a target of tungsten.

Which of the following three statements are correct?

(i) All the energy of the electrons is converted into X-rays.

(ii) The maximum X-ray wavelength obtained is $\frac{hc}{E}$.

(iii) The wavelengths of the characteristic X-ray spectral lines are independent of the potential difference applied to accelerate the electrons.

A (ii) only

B (iii) only

C (i) and (ii) only

D (ii) and (iii) only

30 A detector is used for monitoring an α-source and a reading of 120 counts is observed. After a time equal to the half-life of the α-source, the reading has fallen to 64 counts.

If a 5 mm thick lead sheet is inserted between the α-source and the detector, the reading would probably be

A 0 count

B 4 counts

C 8 counts

D 32 counts

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INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	
CLASS	INDEX NUMBER

PHYSICS 9749/02

Paper 2 Structured Questions

25 August 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

IMPORTANT

Answer **all** questions.
Please write down your answers in the spaces provided.

The number of marks is given in the brackets [ ] at the end of each question or part question.

Marks will be deducted for using inappropriate number of significant figures or wrong value of *g*.

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1	/10
2	/10
3	/11
4	/11
5	/10
6	/7
7	/21
Penalty	
Total	/80
Percentage	

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\Phi = -\frac{GM}{r}$
temperature,	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{½}}$

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Answer all the questions

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1 **(a)** The theory of gas flow through small diameter tubes at low pressures and at a particular temperature is used to obtain the mass flow rate, Q of gas through the tubes. One equation which occurs in theory is

$$Q = \frac{kr^3(p_1 - p_2)}{l}$$

where, k is a constant with a unit of m^{-1} s,
r is the radius of the tube,
p_1 and p_2 are the pressures at each end of the tube, and
l is the length of the tube.

Use SI base units to show that the equation is homogeneous.

[2]

(b) A ball is thrown against a vertical wall. The path of the ball is shown in Fig. 1.1.

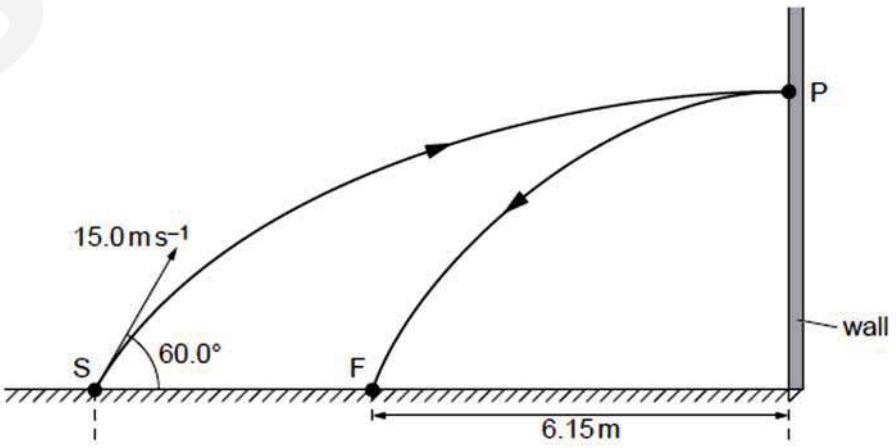

Fig. 1.1

The ball is thrown from S with an initial velocity of 15.0 m s^{-1} at 60.0° to the horizontal.

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The ball hits the wall at P with a velocity that is at right angles to the wall. The ball rebounds to a point F that is 6.15 m from the wall.

Assume that air resistance is negligible,

(i) calculate the time taken for the ball to travel from S to P.

time = ... s [2]

(ii) show that the velocity of the ball immediately after rebounding from the wall is about 4.6 m s^{-1}. Explain your working.

[2]

The mass of the ball is 60×10^{-3} kg.

(iii) Calculate the change in momentum of the ball as it rebounds from the wall.

change in momentum = ... N s [2]

(iv) State and explain whether the collision is elastic or inelastic.

.....

.....

.....

..... [2]

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2 An ideal gas undergoes a cycle of change as shown in Fig. 2.1.

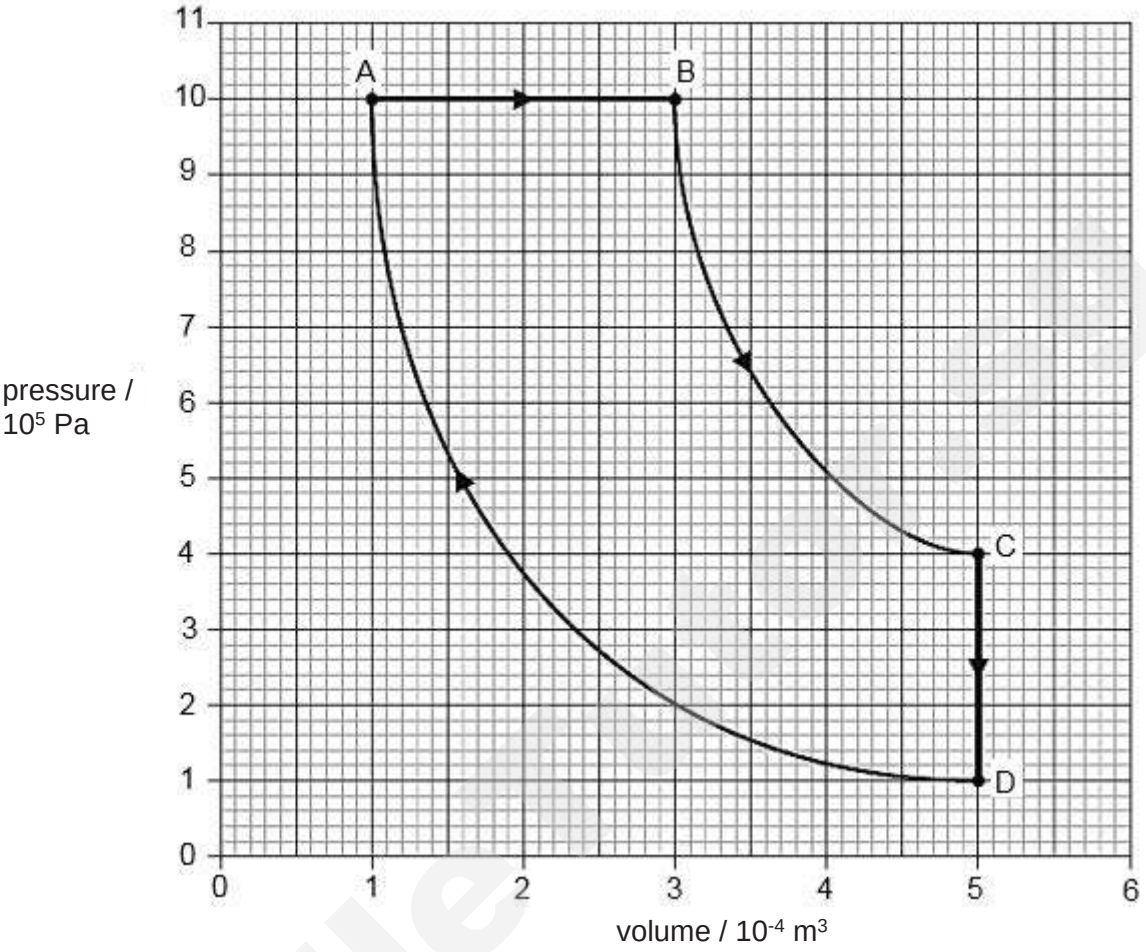

Fig. 2.1

The gas is first compressed within a very short time from D to A. During the process from A to B, it expands at constant pressure. The gas then expands within a very short time from B to C. Finally, from C to D, the volume is kept constant and thermal energy is given out.

(a) (i) Show that the increase in internal energy of the gas as it undergoes the process from A to B is 300 J.

[2]

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(ii) Hence, determine the heat supplied to the gas as it undergoes the process from A to B.

heat supplied = …… J [3]

(b) (i) State and explain the change in internal energy for the cycle DABCD**.**

……

……

……

……... [2]

(ii) The table of Fig. 2.2 gives one of the values for the changes shown on the pressure-volume graph.

	heat supplied to gas	work done on gas	increase in internal energy of gas
A → B			+
B → C			
C → D			
D → A			

Fig. 2.2

Indicate in Fig 2.2 either '+', '-' or '0' for values that are positve, negative or zero respectively. [3]

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3 **(a)** State the Principle of Superposition.

……

……

……

…… [2]

(b) In an experiment to determine the speed of sound, a long tube, fitted with a tap, is filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube, as shown in Fig. 3.1 and Fig. 3.2.

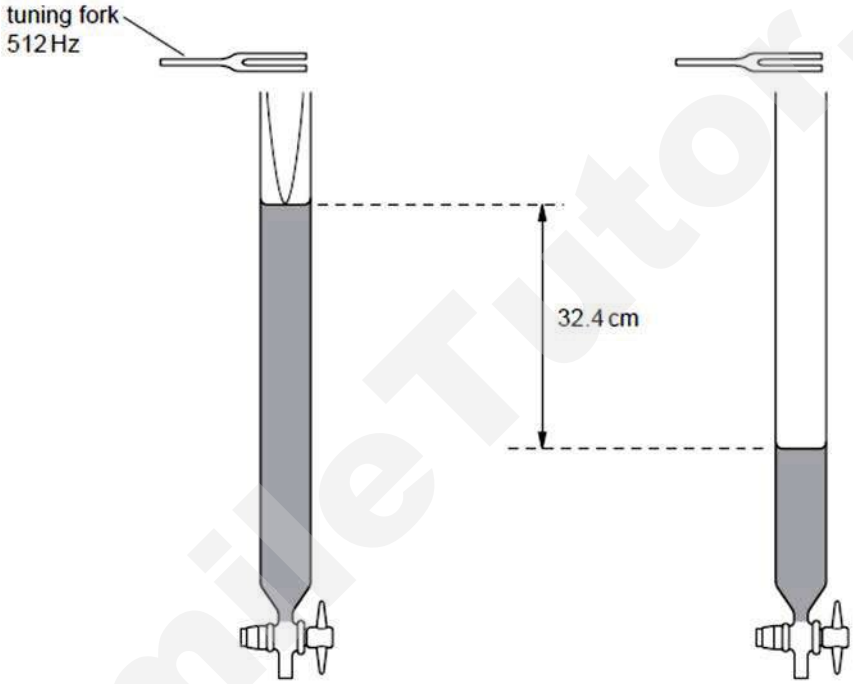

Fig. 3.1 **Fig.3.2**

A loud sound is first heard when the water level is as shown in Fig. 3.1, and then again when the water level is as shown in Fig. 3.2. Fig. 3.1 illustrates a stationary wave produced in the tube.

(i) Explain the formation of a stationary wave in the tube.

……

……

……

……

…… [2]

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(ii) Explain why the loudness of the sound changes as the water level changes.

.....

.....

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.....

.....

..... [3]

(iii) The frequency of the fork is 512 Hz and the difference in the height of the water level for the two positions where a loud sound is heard is 32.4 cm. Calculate the speed of the sound in the tube.

speed of sound = ... m s^{-1} [2]

(iv) The length of the column of air in the tube in Fig. 3.1 is 15.7 cm. Suggest and explain where the antinode of the stationary wave produced in the tube in Fig. 3.1 is likely to be found.

.....

.....

.....

..... [2]

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4 **(a)** Define *electric field strength*.

.....

..... [1]

(b) Two flat parallel metal plates, each of length 12.0 cm, are separated by a distance of 1.5 cm, as shown in Fig. 4.1.

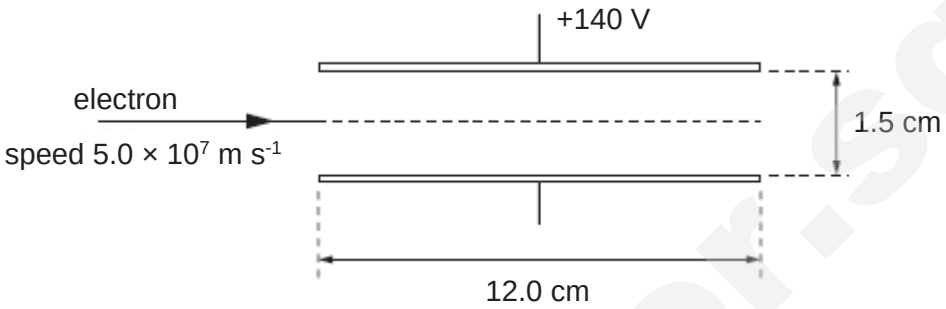

Fig. 4.1

The space between the plates is a vacuum. An upward electric field of field strength 1.40×10^4 N C^{-1} may be assumed to be uniform in the region between the plates and zero outside this region.

Given that the potential of the top plate is +140 V, determine the potential of the bottom plate.

potential = ... V [2]

(c) An electron initially travels parallel to the plates along a line mid-way between the plates, as shown in Fig. 4.1. The speed of the electron is 5.0×10^7 m s^{-1}.

For the electron between the plates,

(i) determine the magnitude and direction of its acceleration,

acceleration = ... m s^{-2}

direction = ... [3]

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(ii) calculate the time for the electron to travel a horizontal distance equal to the length of the plates.

time = ... s [2]

(d) Use your answers in **(c)** to determine whether the electron will hit one of the plates or emerge from between the plates.

[3]

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5 A current I in a copper wire causes the charge carriers to have a drift velocity v, as shown in Fig. 5.1.

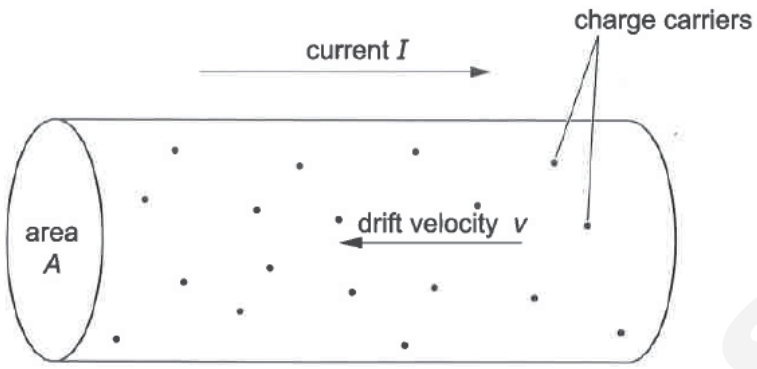

Fig. 5.1

The copper wire has an area of cross-section A. The number density of charge carriers in the wire is n. Each charge carrier has charge of magnitude q.

(a) Derive an equation relating current I to n, A, v and q.

[3]

(b) A copper wire of diameter of 1.8 mm has a uniform current of 17 mA flowing through.

(i) The density of copper is 9.0×10^3 kg m^{-3} and its atomic mass is 63.5 g. Assume that each copper atom contributes roughly one conduction electron, show that the number density of charge carriers in the copper wire is 8.5×10^{28} m^{-3}.

[2]

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(ii) Hence, determine the drift velocity v of the charge carriers.

v = ... m s^{-1} [2]

(iii) One segment of the copper wire is thinner compared to the rest. State and explain how the drift velocity will change when the current flows into the thinner segment.

.....

.....

.....

.....

..... [2]

(c) The drift velocity of the charge carriers is very small. Explain why the room lights turn on quickly when the switch is closed.

.....

.....

..... [1]

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6 A radioisotope thermoelectric generator (RTG) is used to generate electrical power. The RTG obtains its power from the radioactive decay of Plutonium-238. Plutonium-238 has a half-life of 87.7 years.

(a) Define *decay constant* of a radioactive nuclide.

……

…… [1]

(b) Calculate the decay constant of Plutonium-238.

decay constant = …… s^{-1} [2]

(c) When the RTG was manufactured, it contained 1.74×10^{25} atoms of Plutonium-238.

(i) Determine the activity of the Plutonium-238 in the RTG when it was first manufactured.

activity = …… Bq [2]

(ii) Calculate the activity of Plutonium-238 in the RTG 10 years after manufacture.

activity = …… Bq [2]

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7 When a structural engineer is designing a building there will be occasion when a beam has to be used to bridge a gap. The width of the gap is called the span. The engineer makes calculations to ensure that there is not too much sag in the beam. This question concerns how the choice of beam is made.

Sometimes, when the loading is small, a plain wooden beam is sufficient, as shown in Fig. 7.1.

A beam such as this, loaded at its centre, will undergo a maximum depression x given by

$$x = \frac{WL^3}{kab^3}$$

where W is the load at the centre,
a is the width of the beam
b is the depth of the beam and
k is a constant.

When greater loads or greater spans are required, a steel beam may be used. In order to minimize the amount of steel required, the shape of the beam used is as shown in Fig. 7.2.

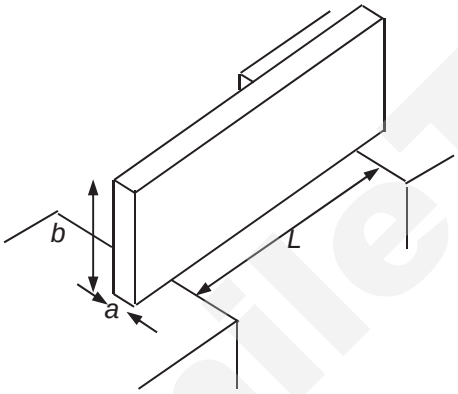

Fig. 7.1

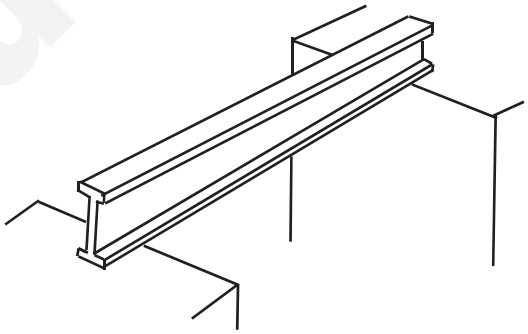

Fig. 7.2

Sometimes, the loading of the beam is uniform, along its length, as shown in Fig. 7.3.

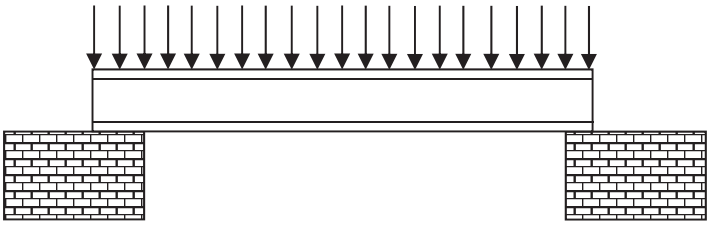

Fig. 7.3

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Sometimes, with complex loading (Fig. 7.4), the moments of the forces have to be calculated.

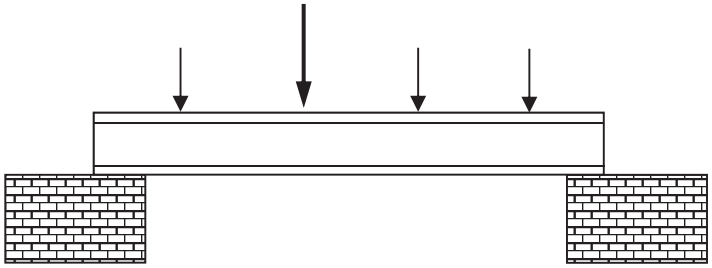

Fig. 7.4

(a) (i) State **one** reason why the structural engineer has to make calculations when using a beam to bridge a gap.

.....

..... [1]

(ii) Write down the reason given in the passage for making the steel beam the shape shown in Fig. 7.2

.....

..... [1]

(iii) The cross-sectional area of the beams shown in Fig. 7.5 are the same.



Fig. 7.5

Suggest why, for beams of the same length, arranged in this manner, one would sag more than the other.

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.....

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.....

.....

..... [3]

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(b) A wooden beam has width 0.050 m, depth 0.10 m and spans 3.0 m. Calculate the maximum load which it can support at its centre for a maximum depression of 0.010 m. Take k to be 3.6×10^{10} Pa for this wood.

maximum load = ... N [2]

(c) A student repeated the experiment for varying spans and obtained the following data for the maximum depression x. Data for some of these are given in Fig. 7.6.

L/ m	x/ mm	$\log_{10}(L/\text{ m})$	$\log_{10}(x/\text{ mm})$
3.000	10.0	0.4771	1.00
2.750	7.7	0.4393	0.89
2.500	5.8	0.3979	0.76
2.000	3.0	0.3010	0.48
1.750	2.0		
1.500	1.3	0.1761	0.11

Fig. 7.6

(i) Complete Fig. 7.6 by calculating values for $\log_{10}(x/\text{mm})$ against $\log_{10}(L/\text{m})$. [1]

(ii) On the axes of Fig. 7.7, plot a graph of $\log_{10}(x/\text{mm})$ against $\log_{10}(L/\text{m})$. [1]

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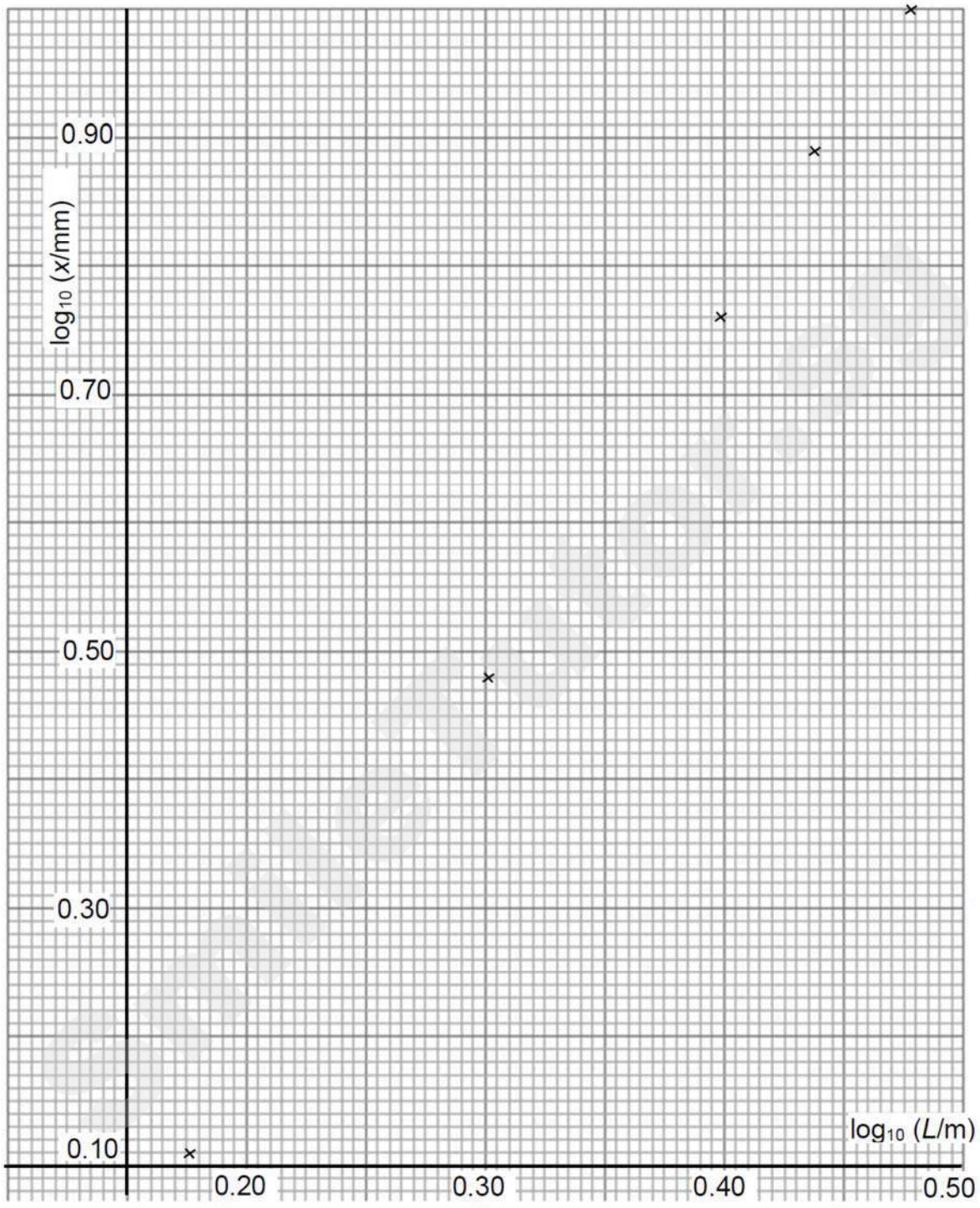

Fig. 7.7

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(iii) Determine the gradient of the graph in Fig. 7.7.

gradient = ... [2]

(iv) Hence discuss whether the data in Fig. 7.6 support the relation $x = \frac{WL^3}{kab^3}$.

.....

.....

.....

.....

..... [2]

(d) A beam across a gap is shown in Fig. 7.8, together with values of the forces acting and their distances from X.

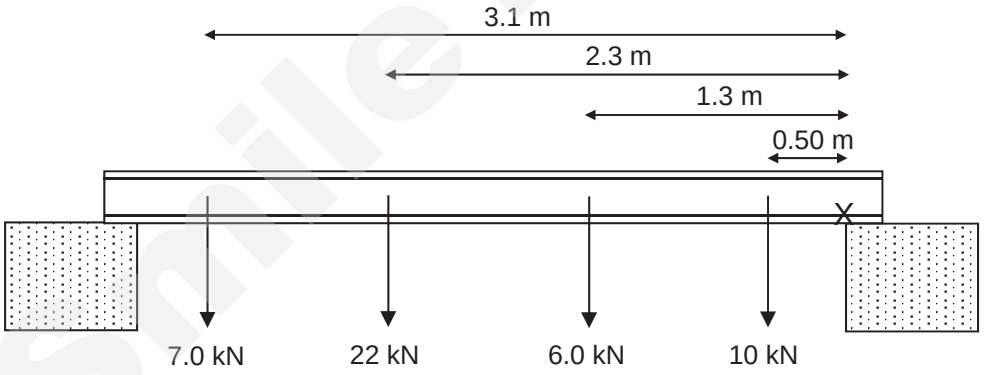

Fig. 7.8

Calculate the total moment of the forces shown about point X.

moment = ... N m [2]

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(e) A steel beam, loaded uniformly as in Fig. 7.3, is allowed to sag by a maximum of 1/360 of the gap it is spanning. A particular beam is used to carry a load of 33 000 N and to span a gap of 4.20 m. A quantity B, known as the bending moment for this loading pattern is given by

$B = \frac{WL}{8}$ and the depression x at the centre is given by

$x = \frac{BL^3}{c}$ where c has the value of 3.35×10^8 N m^3.

Calculate

(i) the bending moment B,

bending moment = ... N m [1]

(ii) the actual amount x of sag.

x = ... m [1]

(f) The final check on the suitability of any beam is to ensure that it is strong enough. This is done, using a table of values, to find the allowable bending stress.

(i) For the beam in **(e)**, two constants P and Q, without units, are found from the dimensions of the beam and the gap it is spanning.

For this beam P = 21 and Q = 170. Use Fig. 7.9 to find the allowable bending stress.

allowable bending stress / MPa				
	P			
Q	15	20	25	30
160	111	96	88	82
170	106	93	83	77
180	102	89	80	73

Fig 7.9

allowable bending stress = ... MPa [2]

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(ii) The beam is safe to use if

$$\frac{\text{bending moment}}{\text{allowable bending stress}} < 2.0 \times 10^{-4} \text{ m}^3$$

Use this relationship to determine whether the beam is safe under these conditions.

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……

……

……

…… [2]

END OF PAPER

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JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9749/03

Paper 3 Longer Structured Questions **14 September 2017**

Candidates answer on the Question Paper. **2 hours**
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer only **one** question.

At the end of the examination, fasten all your work securely together.
The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/10
2	/8
3	/9
4	/7
5	/10
6	/9
7	/7
Section B	
8	/20
9	/20
Significant Figures	
Total	/**80**

This document consists of **25** printed pages and **1** blank page.

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\Phi = -\frac{GM}{r}$
temperature,	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{½}}$

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Section A

For Examiner's Use

Answer **all** the questions in this section.

1 Piling works are commonly done before construction of high rise buildings. Fig.1.1 shows a pile of mass 300 kg being driven into the ground by a pile driver of mass 100 kg.

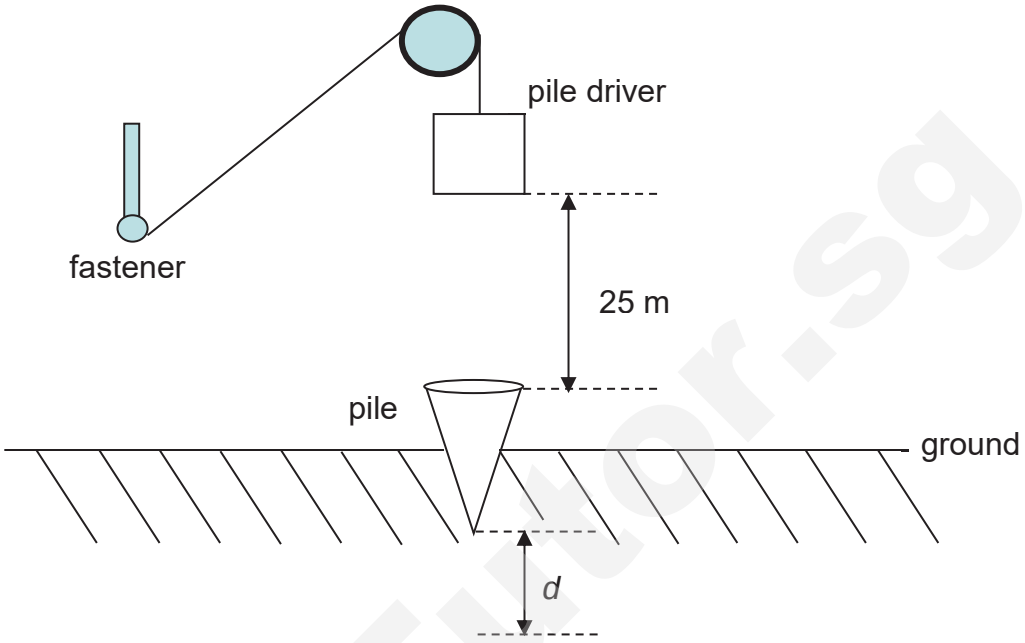

Fig. 1.1

The pile driver is lifted to a height of 25 m above the pile and the fastener is released. The pile driver then falls freely from rest and upon impact with the pile, they stick together. The pile is then driven a distance *d* into the ground before both the pile and driver comes to a stop.

(a) Neglecting air resistance, determine

(i) the speed of the pile driver just before impacting the pile and,

speed = ... m s^{-1} [2]

(ii) the joint speed of the pile and pile driver after the impact.

joint speed = ... m s^{-1} [2]

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(b) The variation of the external resistive force, F on the pile and driver with time immediately after impact, until they stop at a distance d into the ground 0.18 s later is shown in Fig. 1.2.

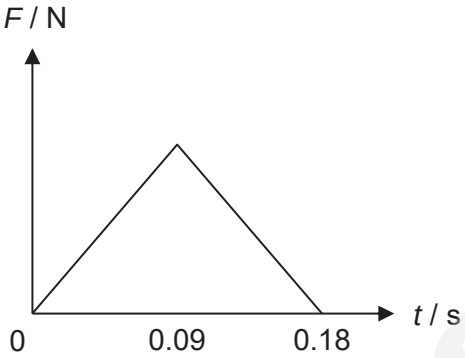

Fig. 1.2

(i) Determine,

1. the change in momentum of the pile and driver from t = 0 s to t = 0.18 s, and

change in momentum = ... kg m s^{-1} [2]

2. the average force, F_{ave} acting on the pile and driver during this period.

average force, F_{ave} = ... N [2]

(ii) Hence, by applying the principle of conservation of energy, determine the stopping distance, d of the pile and driver.

stopping distance, d = ... m [2]

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[Turn over

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2 **(a)** **(i)** On Fig. 2.1, draw lines to represent the gravitational field outside an isolated uniform sphere.

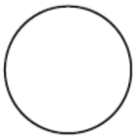

Fig. 2.1

(ii) A second sphere has the same mass but a smaller radius. Suggest what difference, if any, there is between the patterns of field lines for the two spheres.

.....

.....

.....

..... [3]

(b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.98×10^{24} kg concentrated at its centre, as illustrated in Fig. 2.2.

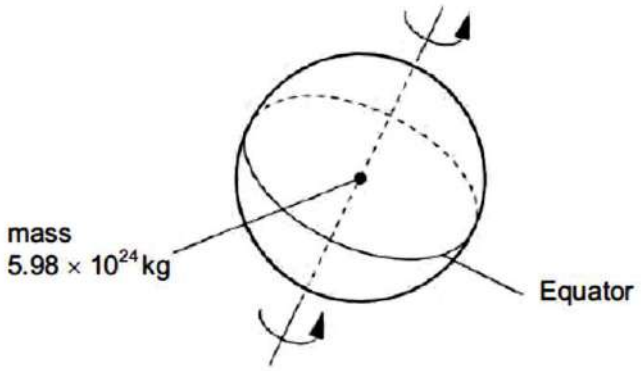

Fig. 2.2

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.00 day (8.64×10^4 s).

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Calculate, to three significant figures,

(i) the gravitational force F_G of attraction between the mass and the Earth,

F_G = ... N [1]

(ii) the centripetal force F_C on the 1.00 kg mass,

F_C = ... N [1]

(iii) the difference in magnitude of the forces.

difference = ... N [1]

(c) By reference to your answers in **(b)**, suggest, with a reason, a value for the acceleration of free fall at the Equator.

.....

.....

..... [2]

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3 **(a)** An ideal gas is said to consist of molecules that are hard elastic identical spheres.

State two further assumptions of the kinetic theory of gases.

.....

.....

.....

.....

..... [2]

(b) The number of molecules per unit volume in an ideal gas is n.

If it is assumed that all the molecules are moving with speed v_x in the x-direction, the pressure p exerted by the gas on the walls of the vessel is given by

$$p = nmv_x^2$$

where m is the mass of one molecule.

Explain the reasoning by which this expression is modified to give the formula

$$p = \frac{1}{3}nm\langle c^2 \rangle$$

.....

.....

.....

..... [2]

(c) The density of an ideal gas is 1.2 kg m^{-3} at a pressure of 1.0×10^5 Pa and a temperature of 27 °C.

(i) Calculate the root-mean-square (r.m.s.) speed of the molecules of the gas at 27 °C.

speed = ... m s^{-1} [3]

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(ii) Calculate the mean-square speed of the molecules at 207 °C.

mean-square speed = …… $m^2 s^{-2}$ [2]

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4 **(a)** State how a *polarised* transverse wave differs from an *unpolarised* transverse wave.

.....

.....

..... [1]

(b) Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at θ and 62° respectively, to that of the first, as shown in Fig. 4.1.

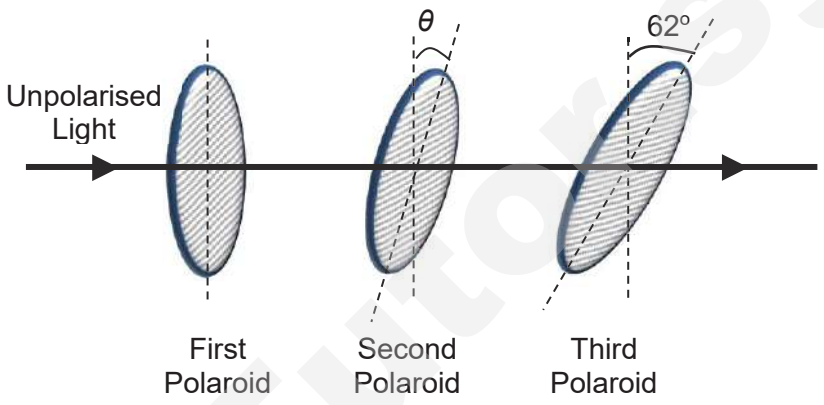

Fig. 4.1

When an unpolarised light of amplitude A_0 is incident on the stack of polaroids, the light has amplitude of A_1 after it passes through the first polaroid, A_2 after it passes through the second polaroid and A_3 after it passes through the third polaroid.

(i) If $\theta = 90°$, determine A_3 in terms of A_1.

A_3 = ... [1]

(ii) If the second polaroid is rotated such that $\theta = 23°$

1. Show that $A_3 = 0.715\ A_1$.

[2]

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2. The intensity of the unpolarised light after it passes through the first polaroid is reduced to half.

Determine the percentage reduction of the intensity after the unpolarised light passes through the stack of three polaroids.

percentage reduction = …….. % [3]

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5 In Fig. 5.1, S_1 and S_2 are two small loudspeakers, initially placed at position Y and Z, which emit sound waves of the same intensity and wavelength. A microphone for detecting sound intensity is placed at point P such that YP = ZP.

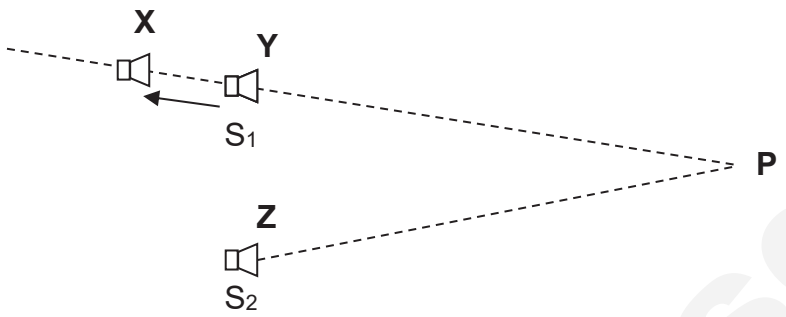

Fig. 5.1

(a) (i) One of the conditions required for the formation of a well-defined interference pattern is that the two sources are coherent.

State what is meant by coherent sources and suggest how *coherence* of S_1 and S_2 can be achieved in this case.

.....

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..... [2]

(ii) Given that S_1 and S_2 are in phase, the speaker S_1 is moved slowly from Y to X along the line between these two points. As S_1 is moved, the sound detected at P fluctuates in intensity.

Explain this observation.

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..... [3]

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(iii) In moving S_1 from point Y to point X as shown in Fig. 5.1, the intensity of the sound at P changes from a maximum to a minimum. The distance YX = 0.082 m.

Calculate the wavelength of the sound emitted by the sources.

wavelength = ... m [1]

(iv) S_1 remains at the point X and the frequency *f* of the sound emitted from both S_1 and S_2 is gradually increased until a maximum sound intensity is first detected at P. This occurs when *f* = 4100 Hz.

Estimate a value for the speed of sound.

speed of sound = ... m s^{-1} [2]

(b) Explain why for the maxima and minima to be observable, the amplitude of the two sound sources have to be approximately the same.

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..... [2]

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6 Negatively-charged particles are moving through a vacuum in a parallel beam. The particles have speed v.

The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 6.1.

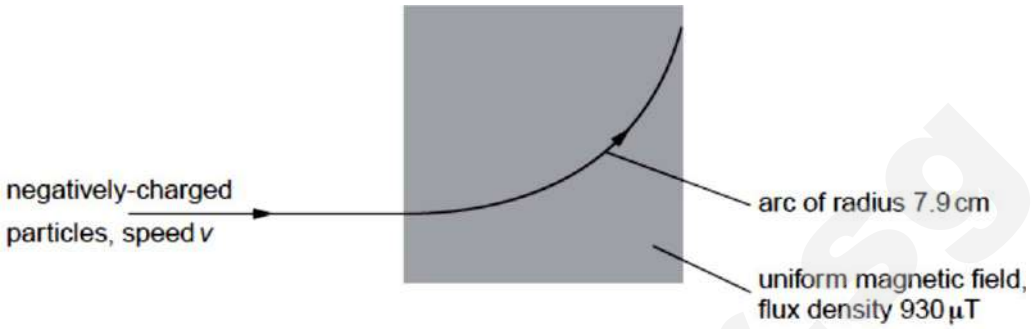

Fig. 6.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 kV m^{-1}, the particles are undeviated as they pass through the region of the fields.

(a) On Fig. 6.1, mark with an arrow the direction of the electric field. [1]

(b) For the negatively-charged particles, calculate

(i) the speed v,

v = ... m s^{-1} [2]

(ii) the ratio $\frac{\text{charge}}{\text{mass}}$.

Explain your working.

ratio = ... C kg^{-1} [3]

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(c) Given that the negatively charged particles in Fig. 6.1 are electrons, explain the effects on the path of the single particle if an alpha particle were to enter the region of magnetic and electric field with the same speed.

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..... [3]

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7 **(a)** The energy of the sun is produced by the thermonuclear fusion reaction represented by

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e + \text{energy}$$

You may use the following masses in answering this question:

Mass of ${}^{1}_{1}H$ = 1.007825 u

Mass of ${}^{4}_{2}He$ = 4.002603 u

Mass of ${}^{0}_{+1}e$ = 0.000549 u

(i) Determine the energy released per nuclear reaction.

Energy released per reaction = …… MeV [2]

(ii) Given the Earth is at a distance 1.5 x 10^{11} m away from the Sun, and 1.35 kW m^{-2} of the Sun's energy is incident on Earth per second per unit area, determine the rate at which hydrogen nuclei are undergoing thermonuclear fusion in the Sun.

Rate = …… s^{-1} [3]

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(b) Fig. 7.1 shows the variation with nucleon number A of the binding energy per nucleon E of nuclei.

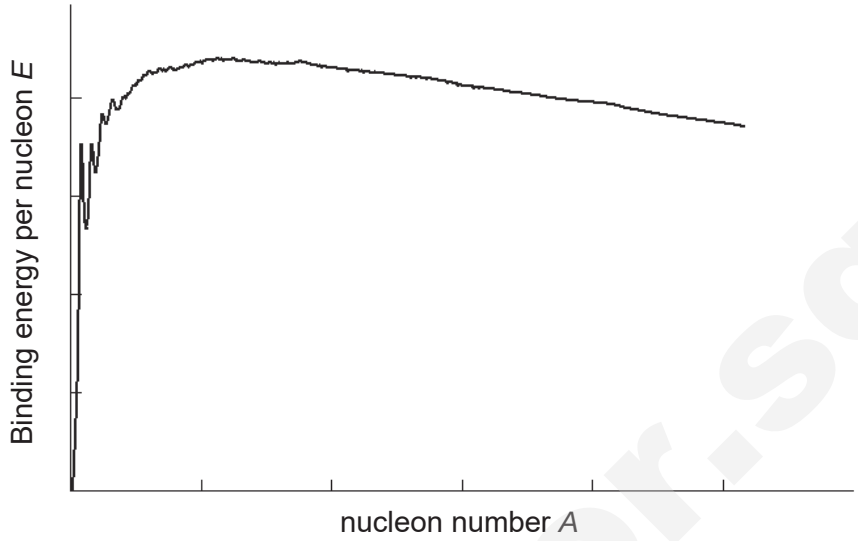

Fig. 7.1

With the aid of Fig. 7.1, explain why more energy per nucleon is released in fusion than in fission.

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..... [2]

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Section B

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Answer **one** question in this section in the spaces provided.

8 A light spring is suspended from a fixed point. A bar magnet is attached to the end of the spring of spring constant k, as shown in Fig. 8.1.

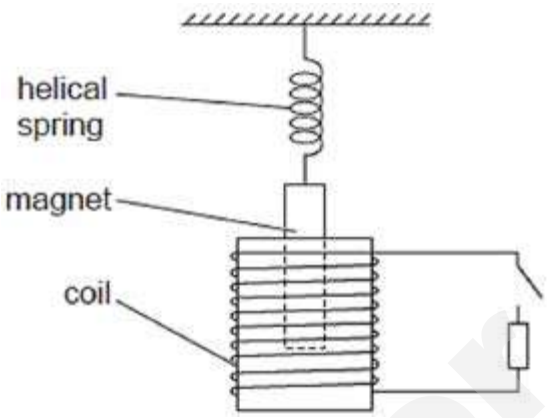

Fig. 8.1

One pole of the magnet is situated in a coil of wire. The coil is connected in series with a switch and a resistor.

(a) Initially, the switch is open. When the magnet is given a small vertical displacement and then released, the restoring force F acting on the magnet is related to its vertical displacement y by the expression

$$F = - ky$$

(i) Explain why the expression suggests that the magnet is performing simple harmonic motion.

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..... [2]

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(ii) The variation with time t of the vertical displacement y of the magnet is shown in Fig. 8.2.

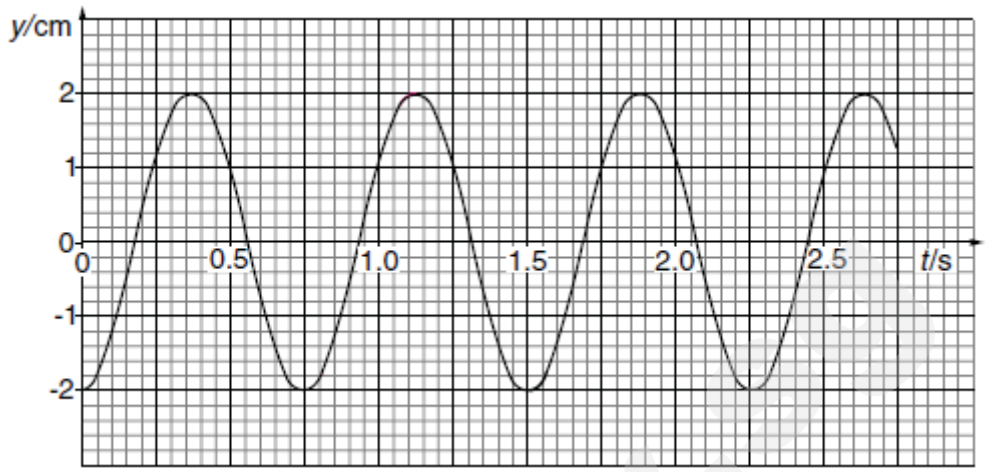

Fig. 8.2

The mass of the magnet is 130 g.

Use Fig. 8.2 to

1. explain why the graph suggests that the oscillations are undamped,

.....

..... [1]

2. calculate the angular frequency ω, and

ω = ... rad s^{-1} [2]

3. determine the displacement of the magnet at which its kinetic energy is equal to its potential energy.

displacement = ... m [3]

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(b) An induced e.m.f. is measured across the terminals of the coil during the oscillations of the magnet.

(i) On Fig. 8.3, sketch a graph to show the variation with time of the e.m.f. *E* induced in the coil.

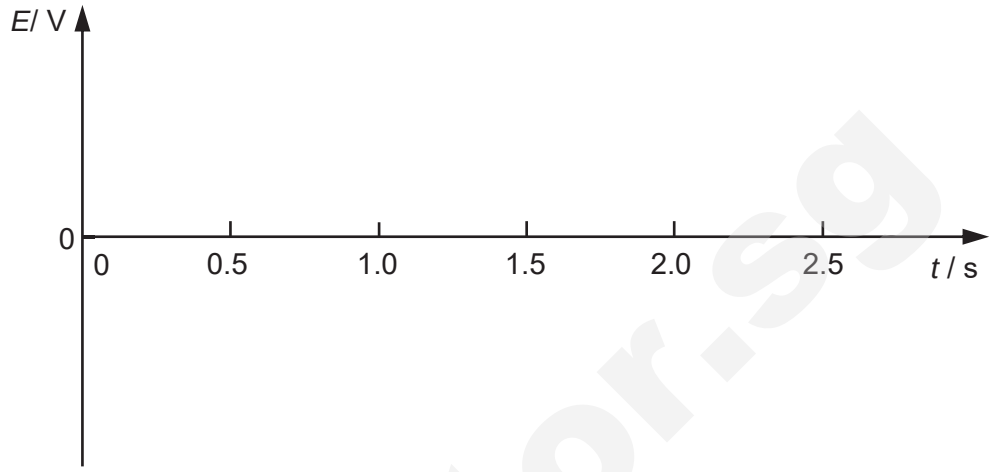

Fig. 8.3 [2]

(ii) Using the principles of electromagnetic induction, explain the shape of the graph sketched in Fig. 8.3.

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..... [3]

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(c) The switch is now closed. During 10 complete oscillations of the magnet, the amplitude of the vibration is seen to decrease where the magnet loses 20% of its energy.

(i) Use Faraday's law of electromagnetic induction to explain why the amplitude of the oscillation decreases.

.....

.....

.....

.....

.....

..... [3]

(ii) Determine the new amplitude of oscillation after 10 complete oscillations.

amplitude = ... m [2]

(iii) Explain why the amplitude in **(c)(ii)** reduces when the resistance of the resistor is reduced.

.....

.....

.....

..... [2]

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9 **(a)** Einstein's interpretation of the photoelectric effect on a metal surface led him to the formulation of the photoelectric equation given by $hf = \Phi + E_k$

(i) State what the following terms represent.

hf : .....

Φ : .....

E_k : ..... [2]

(ii) State the conservation law that the photoelectric equation follows.

..... [1]

(iii) In a photoelectric experiment, a metal surface is illuminated with a beam of monochromatic radiation, of wavelength 300 nm and intensity 0.500 W m^{-2}, over an area of 4.50×10^{-5} m^2. Φ has a value of 2.03 eV.

1. Calculate the stopping potential.

stopping potential = ... V [2]

2. The photoelectric quantum yield is defined as the ratio

$$\frac{\textit{no. of photoelectrons emitted per sec}}{\textit{no. of photons incident per sec}}.$$

Given that the photoelectric quantum yield of the metal surface is 5.70×10^{-7}, determine the maximum photoelectric current.

maximum photoelectric current = ... A [3]

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(b) An electron beam, capable of firing individual electrons, is directed at a wall made of a gold-coated silicon membrane. The wall had two 62 nm wide slits in it with a centre-to-centre separation of 272 nm.

The electrons were created at a tungsten filament and accelerated across 600 V. After passing through the double slit, they were detected using a suitable screen placed 240 mm behind. A resulting pattern formed after several hours is shown in Fig. 9.1. *d* is the separation between the centres of adjacent bright spots.

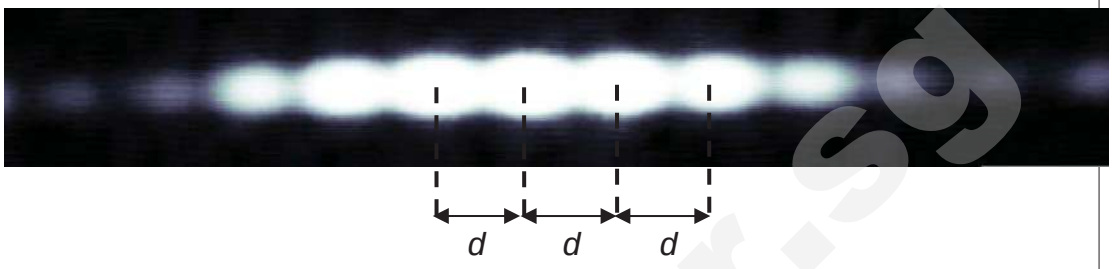

Fig. 9.1

(i) Suggest the significance of this experiment.

..... [1]

(ii) Show that the momentum of the electron when it is at the double slit wall is 1.32×10^{-23} N s.

[2]

(iii) Hence determine the separation *d*.

d = ... m [3]

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(c) Fig. 9.2 below shows some of the energy levels (in electron-volts) of an atom X.

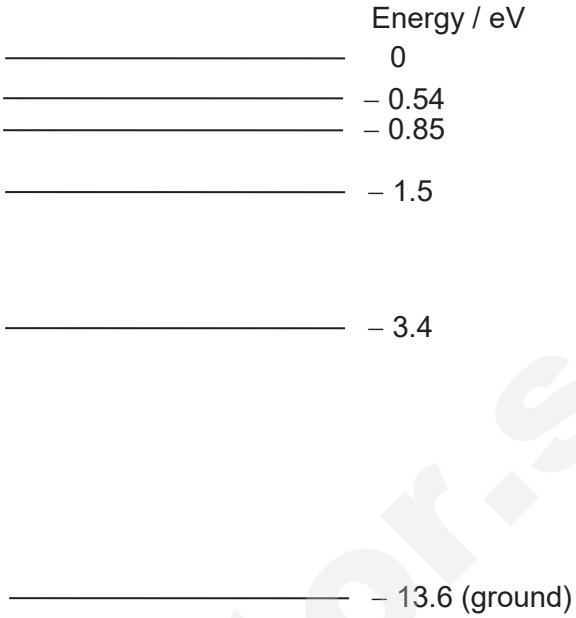


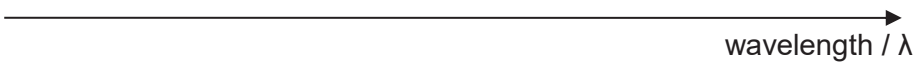
Fig. 9.2

Cool vapour of X at low pressure is bombarded with electrons that are accelerated from rest through an accelerating potential of 12.8 V.

(i) Determine the number of different wavelengths of radiation that will be emitted.

number of wavelengths = ... [2]

(ii) Draw the spectral lines in the axis given below. Label the line corresponding to the highest energy radiation.



[2]

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(iii) Determine the wavelength of the highest energy radiation.

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wavelength = …… m [2]

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PHYSICS 9749/04

Paper 4 Practical

17 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Shift
Laboratory

IMPORTANT

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/14
2	/9
3	/20
4	/12
Penalty	
Total	/**55**
Percentage	

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You may not need to use all of the materials provided.

1 In this experiment, you will investigate how the motion of a thin card shape depends on its size.

You have been provided with two sets of card strips of different lengths. Spare strips are available if necessary.

(a) (i) Measure and record the length L of the **longer** strip of card as shown in Fig. 1.1.

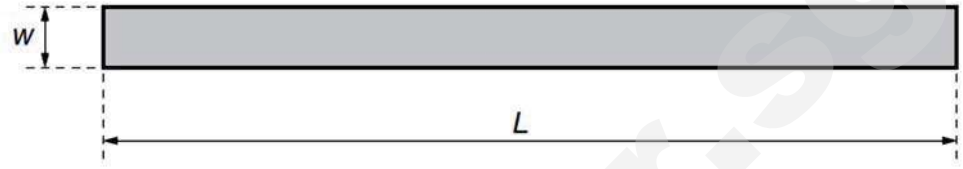

Fig. 1.1

L = ... [1]

(ii) Estimate the percentage uncertainty in your value of L.

percentage uncertainty = ... [1]

(b) (i) Using a vernier caliper, measure and record the width w of the **same** strip of card as shown in Fig. 1.1.

w = ... [1]

(ii) Determine the surface area A of the strip, using the equation

$$A = L\,w$$

A = ... [1]

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(c) **(i)** Use tape to stick the two **longer** strips together, so that they do not overlap, to make the shape shown in Fig. 1.2.

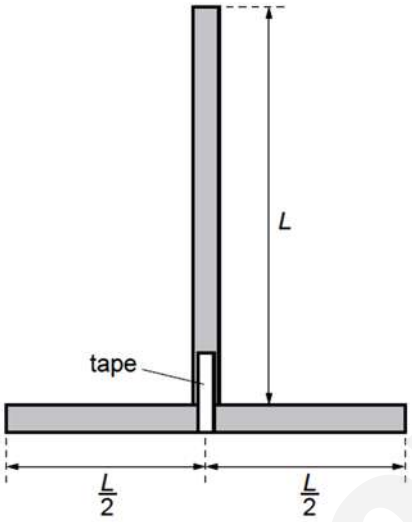

Fig. 1.2

(ii) Use the pin to make a hole at the top of the vertical strip as shown in Fig. 1.3.

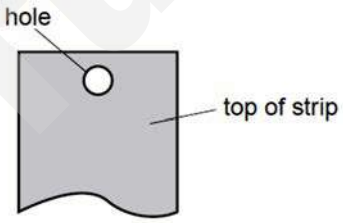

Fig. 1.3

The hole should be central and as near to the top as possible and be large enough for the card to swing freely on the pin.

(iii) Use the cork and pin, suspend the card shape as shown in Fig. 1.4.

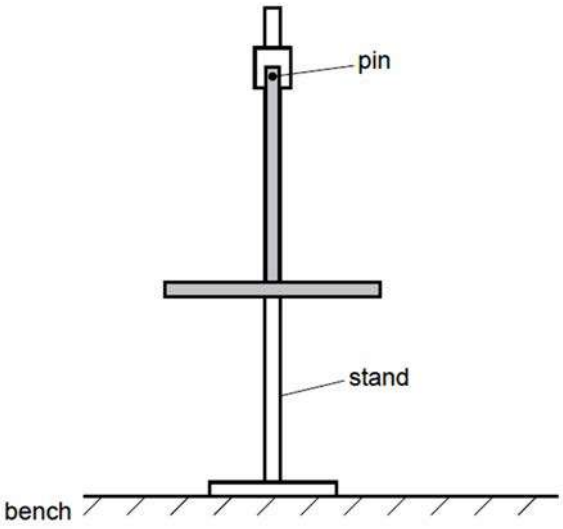

Fig. 1.4

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(d) Move the card shape to the left. Release the shape and observe its movement. The card will move to the right and then to the left again, completing a swing as shown in Fig. 1.5.

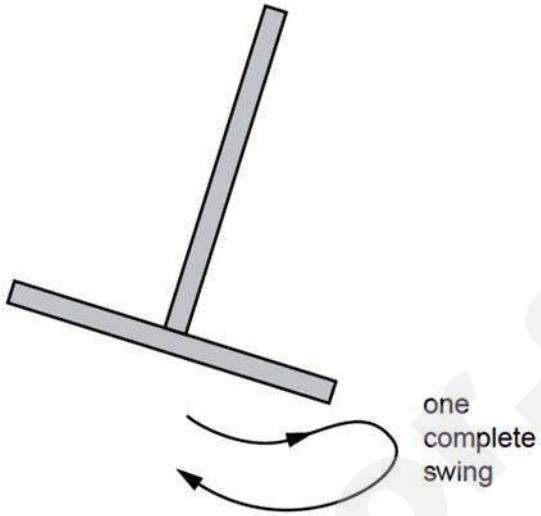

Fig. 1.5

The time taken for one complete swing is *T*.
By timing several of these complete swings, determine an accurate value for *T*.

T = ... [3]

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(e) It is suggested that T^2 is directly proportional to L for this shape.

Use the two card strips that are **shorter** to take further measurements to investigate this suggestion.
State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

……

……

……

……

……

…… [5]

(f) **(i)** Describe a significant source of uncertainty or limitation of the procedure for this experiment.

……

……

…… [1]

(ii) Describe an improvement that could be made to this experiment to address the source of error identified in **(f)(i)**. You may suggest the use of other apparatus or different procedures.

……

……

…… [1]

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2 In this experiment you will investigate how the rate of heat energy transferred from a heater depends on the voltage across its resistance.

(a) **(i)** Pour water into the measuring cylinder to the 50 ml mark.

(ii) Pour the water from the measuring cylinder into the empty beaker.
Determine and record the mass m of water in the beaker.
(1 ml of water has a mass of 1 g)

m = ... [1]

(b) **(i)** Set up the circuit shown in Fig. 2.1.

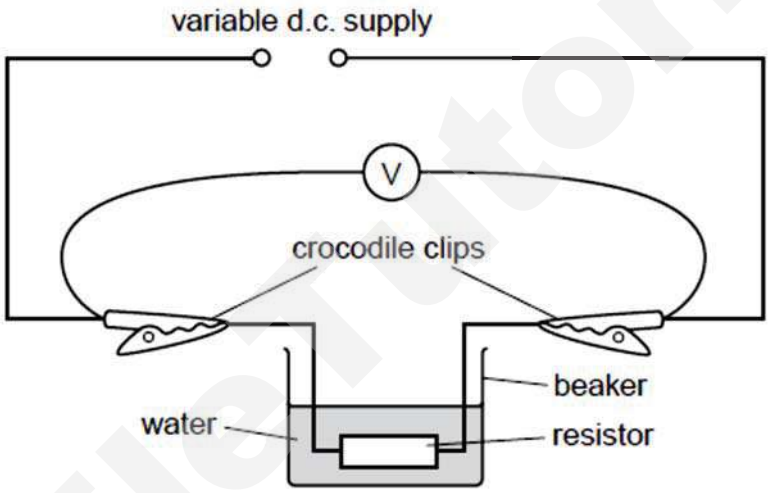

Fig. 2.1

(ii) Adjust the output of the power supply to 6 V.

(iii) Switch on the power supply. Measure and record the voltmeter reading V.
Switch off the power supply.

V = ... [1]

(c) Measure and record the temperature θ_1 of the water in the beaker.

θ_1 = ...

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(d) **(i)** Switch on the power supply and start the stopwatch.

(ii) After four minutes, measure and record the temperature θ_2 of the water. Switch off the power supply.

θ_2 = ... [1]

(iii) Calculate and record the temperature rise (θ_2 - θ_1).

(θ_2 - θ_1) = ... [1]

(e) It is suggested that the relationship between V, θ_1 and θ_2 is

$$V^2 = \frac{mcR}{t}(\theta_2 - \theta_1)$$

where, c is the specific heat capacity of water,
R is the resistance of the resistor (10 Ω) in Fig. 2.1 and,
t is the heating duration.

Use your data in **a(ii)**, **b(iii)** and **(d)(iii)** to calculate c.

c = ... [2]

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(f) The design of the resistance heater used in this experiment has limitations in providing a high rate of heat transfer to water.

Suggest changes that could be made to the design of the heater to improve the rate of heat transfer to water for large volume heating in industrial applications. Explain your answer.

……

……

……

……

……

……

……

…… [3]

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3 In this experiment you will determine the resistivity of a metal in the form of a wire.

(a) **(i)** Measure and record the diameter d of the short sample of the wire placed in the clear container.

d = ... [1]

(ii) Calculate the cross-sectional area A of the wire using the formula

$$A = \frac{\pi d^2}{4}.$$

A = ... [1]

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(b) **(i)** Using the wire attached to the meter rule, set up the circuit shown in Fig. 3.1.

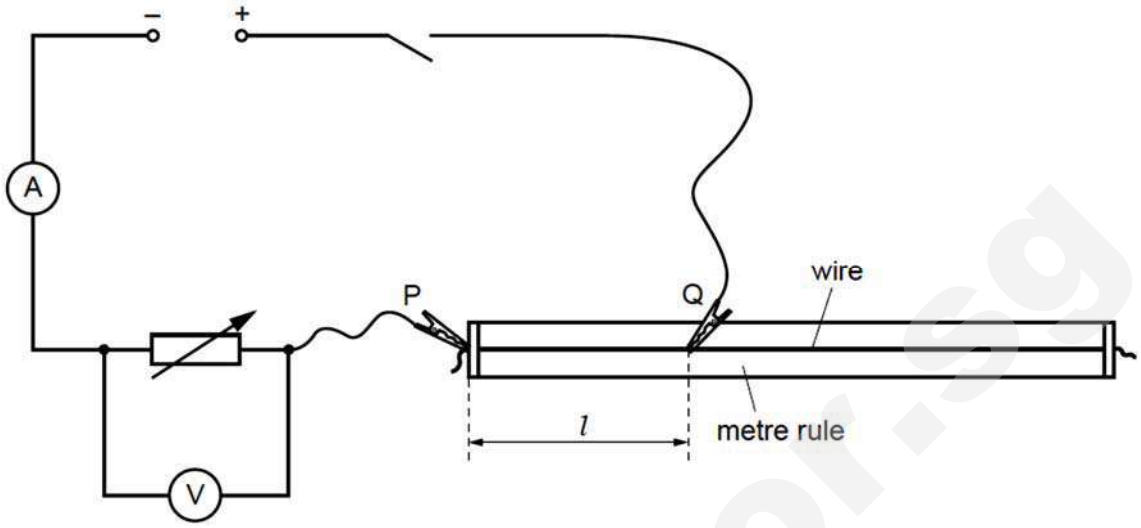

Fig. 3.1

There are two crocodile clips P and Q.

P will remain in the same position throughout the experiment.

Q can be moved to different positions along the wire.

(ii) Position the slider approximately three quarter-way along the rheostat (variable resistor).

(iii) Attach Q approximately 30 cm along the wire away from P.

(iv) Close the switch.

(v) Measure and record the length l, of the wire between P and Q.

Record the voltmeter reading V.

l = ...

V = ... [1]

(vi) Record the ammeter reading I.

I = ... [1]

(vii) Open the switch.

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(c) **(i)** Reposition Q at a new distance l from P.

(ii) Close the switch.

(iii) Adjust the slider of the rheostat until the ammeter reading is the same value as in **(b)(vi)**.

(iv) Measure and record the length l, of the wire between P and Q.

Record the voltmeter reading V.

l = ……

V = ……

(v) Open the switch.

(d) Repeat **(c)** until you have six sets of readings for l and V.

For each value of l, adjust the slider on the rheostat so that the ammeter reading I remains constant at the value in (b)(vi).

You may find it helpful to copy your value from **(b)(vi)** here.

I = ……

[7]

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(e) It is suggested that the quantities of V and l are related by the equation

$$\frac{V}{l} = \frac{M}{l} - N$$

where M and N are constants.

Plot a suitable graph to determine M and N.

M = ……..

N = …….. [4]

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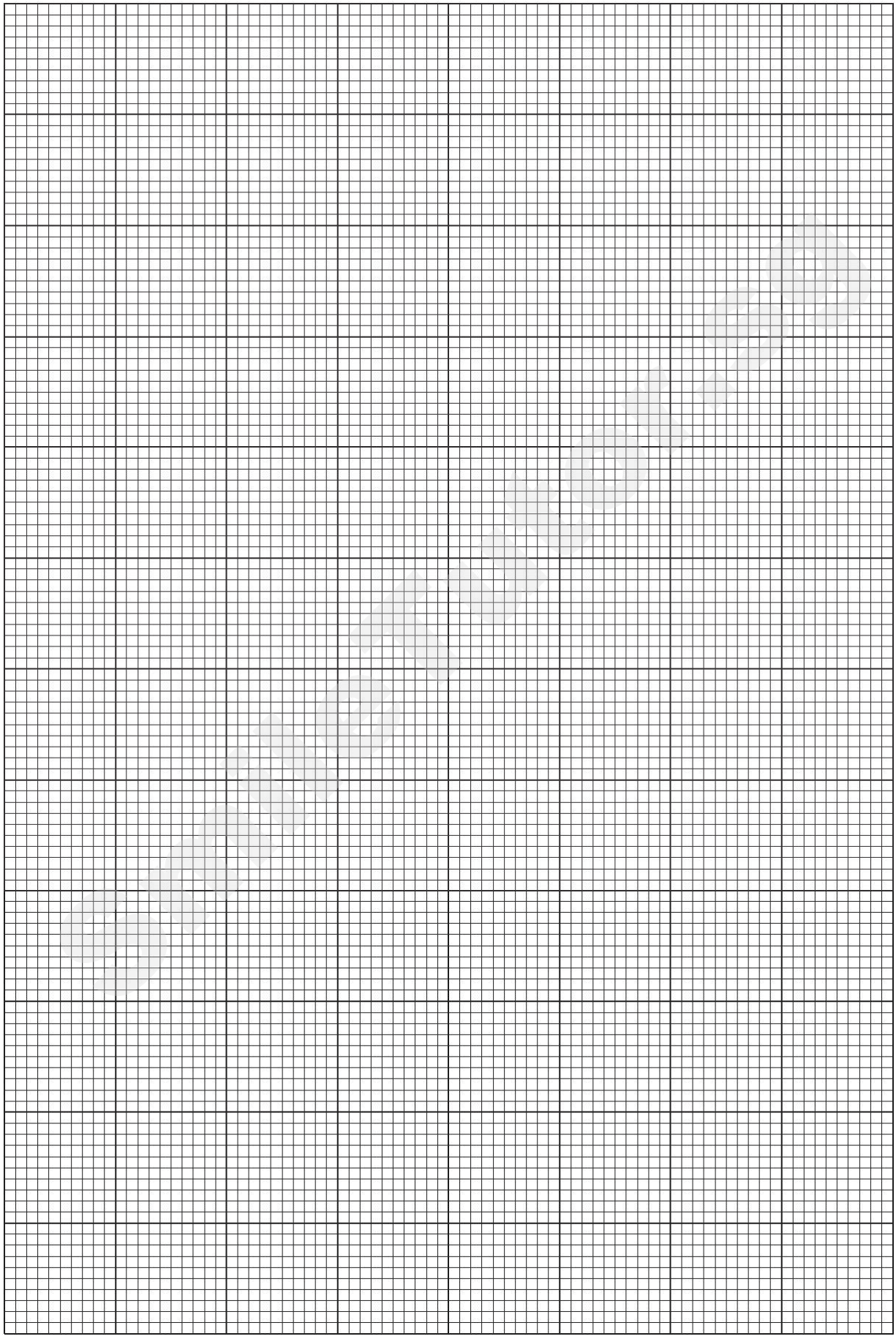

[3]

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(f) Comment on any anomalous data or results that you may have obtained. Explain your answer.

……

……

……..[1]

(g) The resistivity ρ of the material of the wire, in Ω m, can be found using the relationship

$$\rho = \frac{NA}{I}$$

when N is expressed in V m^{-1}, A in m^2 and I in A.

Using your answers in **(a)(ii)**, **(b)(vi)** and **(e)**, calculate a value for ρ.

ρ = …….. Ω m [1]

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Please turn over for Question 4.

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4 A student investigates the power dissipated by a lamp connected to a model wind turbine as shown in Fig. 4.1.

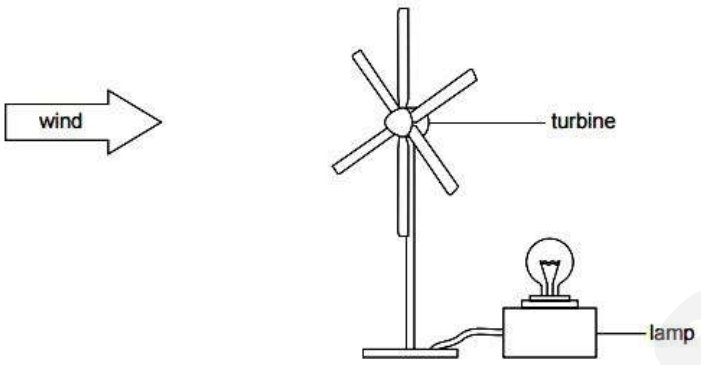

Fig. 4.1

The power P dissipated in the lamp depends on the angle θ between the axis of the turbine and the direction of the wind, as shown by the top view in Fig. 4.2.

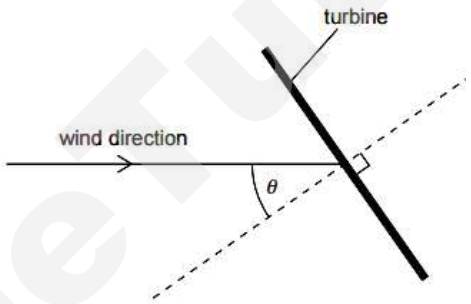

Fig. 4.2

It is suggested that

$$P = k \cos \theta$$

where k is a constant.

Design a laboratory experiment to test the relationship between P and θ and determine a value for k. You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the constant k is determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

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Diagram

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Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	**A**	7	**D**	13	**A**	19	**C**	25	**D**
2	**B**	8	**D**	14	**A**	20	**D**	26	**A**
3	**B**	9	**D**	15	**D**	21	**A**	27	**C**
4	**D**	10	**A**	16	**C**	22	**B**	28	**C**
5	**D**	11	**B**	17	**B**	23	**D**	29	**B**
6	**C**	12	**D**	18	**C**	24	**B**	30	**C**

1 *Ans: **A***

Let the top mark be a and the lower mark be b. Let the time the ball passes the top mark be t_a and when it passes the lower mark, t_b.

Hence the speed v of the ball is $\frac{b-a}{t_b-t_a}=\frac{270}{2.00}$

$$\frac{\Delta v}{v}=\frac{(\Delta b+\Delta a)}{b-a}+\frac{(\Delta t_b+\Delta t_a)}{t_b-t_a}$$

$$\frac{\Delta v}{v}=\frac{2\text{ mm}}{270\text{ mm}}+\frac{0.04\text{ s}}{2.00\text{ s}}$$

$$\frac{\Delta v}{v}=\frac{2}{270}+\frac{0.04}{2.00}$$

Comments

2 *Ans: **B***

$$s=ut+\frac{1}{2}gt^2$$

$$L=0+\frac{1}{2}gt^2 \text{ ---------(1)}$$

$$s=\frac{1}{2}gt^2\left(\frac{1}{4}\right)$$

$$s=0.25L$$

Comments

3 *Ans: **B***

Statement A: False
This is a violation of Newton's Third Law.

Statement B: True
In compliance with Newton's Third Law.

Statement C: False
If forces acting on the trolley were to be in equilibrium, then the trolley would not accelerate.

Statement D: False
If this statement were true, then according to Newton's Second Law of motion, the trolley's acceleration would be zero and it will be moving at constant speed.

Comments

4 *Ans: **D***

Let the volume of the ice block be *V*.

Comments

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When fully submerged, volume of fluid displaced = volume of ice block = V

Upthrust = weight of fluid displaced = density of fluid x volume of fluid displaced x g

= 1.0 x V x g = $V g$

When floating, block is in equilibrium, so:

Upthrust = weight of ice block = density of ice block x volume of ice block x g

= 0.9 x V x g = 0.9 $V g$

Hence, ratio of (upthrust when fully submerged) / (upthrust when floating) = $V g$ / 0.9$V g$ = 1.1

5 *Ans:* ***D***

Comments

Statement A: False
There must be a force at the pivot for the arm to be in equilibrium.

Statement B: False
When the load is moved nearer to the pivot the clockwise moment due to the load about the pivot will decrease. Hence, the anticlockwise moment by the force from the biceps about the same pivot to maintain equilibrium of the arm will also decrease. Therefore, the force from the biceps will be smaller.

Statement C: False
We must consider the vector sum of the weights rather than scalar addition

Statement D: True
This statement is correct, otherwise the biceps itself will not be in equilibrium as shown.

6 *Ans:* ***C***

Comments

Rate of change of GPE = (m/t)gh = 1.77×10^8
Efficiency = (Useful power output/Power input) $\times$ 100%
= $(100 \times 10^6 / 1.77 \times 10^8) \times 100\%$
= 57%

7 *Ans:* ***D***

Comments

Minimum tension occurs at the top:
$T_1 + W = mv2/r = 12.5$ N
$T_1 = 9.6$ N

Minimum tension occurs at the bottom:
$T_2 - W = mv^2/r = 12.5$ N

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T2 = 15.4 N

8 **Ans: D**

Centripetal force is always perpendicular to the motion,
Thus work done by centripetal force = F × d cos90 = 0

Comments

9 **Ans: D**

(A) The acceleration is always directed towards the central point.
(B) The acceleration and velocity are always 90° out of phase.
(C) The velocity and displacements may be in the same direction or opposite direction.

Comments

10 **Ans: A**

Maximum energy = ½ $m\omega^2 x_0^2$ = 50 J
½ $m\omega^2$ = 50/((100× 10^{-3})^2 = 5000
At 40 mm, $v^2 = \omega^2(x_0^2 - x^2)$
Kinetic energy = ½ $m\omega^2[(100 \times 10^{-3})^2 - (40 \times 10^{-3})^2]$
= 5000[(100 × 10^{-3})^2 – (40 × 10^{-3})^2] = 42 J

Comments

11 **Ans: B**

XY = $\sqrt{(R^2 + (2R)^2} = (\sqrt{3})R$
$F = GMm/XY2 = GMm/3R^2$
$GMm/R^2 = 3F$

When the planets are nearest to each other, distance = R
$F_1 = GMm/R^2 = 3F$

Comments

12 **Ans: D**

Gravitational field at surface, g

$$= \frac{GM}{R^2}$$

$$= \frac{G(\rho V)}{R^2}$$

$$= \frac{G(\rho \frac{4}{3}\pi R^3)}{R^2}$$

$$= \frac{4}{3}G\rho\pi R$$

For planets of the same mean density, $g \propto R$

$$\frac{\text{gravitational field at the surface of planet X}}{\text{gravitational field at the surface of planet Y}} = \frac{R_X}{R_Y} = \frac{1}{2}$$

Comments

13 **Ans: A**

T / K = t / °C + 273.15
t / °C = T / K - 273.15 [a t / °C against T / K graph would have a y-intercept of 273.15]

Comments

14 **Ans: A**

Internal energy can also be changed by the wrok done on the system (expansion or compression)

Comments

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15 **Ans: D**

Comments

Option A is incorrect S should be of higher speed since it is at the equilibrium position.
Option B is incorrect because both should be moving in opposite directions.
Option C is incorrect because kinetic energy of P (being at the amplitude) is 0.
Option D is the answer because acceleration is proportional to displacement from the equilibrium position.

16 **Ans: C**

Comments

Upon reflection, the phase should change by π.
Thus, waves that reach the surface would undergoes a pi phase change and proceed towards the left.

17 **Ans: B**

Comments

A node to antinode = ¼ wavelength

18 **Ans: C**

Comments

For the diffraction grating,
$n\lambda = d\sin\theta$
$(1)\lambda = d\sin30° \Rightarrow d = \lambda / \sin30°$
For the double slit experiment,
$\lambda = ax/D$
$\lambda = (500d)x/(1)$
$\lambda = (500)(\lambda / \sin30°)x/(1)$
$1 = 500x/\sin30°$
$X = 0.001\ m$

19 **Ans: C**

Comments

$KE_i + EPE_i = KE_f + EPE_f$
$0 + qV_i = ½\ mv^2 + qV_f$
$$v = \sqrt{\frac{2q\Delta V}{m}}$$
Since each nuclei is accelerated through the same p.d.
$$v \propto \sqrt{\frac{q}{m}}$$
For the lowest speed, the nuclei has the smallest $\sqrt{\frac{q}{m}}$.
$$\left(\sqrt{\frac{q}{m}}\right)_H = \sqrt{\frac{1}{1}} = 1$$
$$\left(\sqrt{\frac{q}{m}}\right)_{He} = \sqrt{\frac{2}{4}} = 0.707$$
$$\left(\sqrt{\frac{q}{m}}\right)_{Li} = \sqrt{\frac{3}{7}} = 0.655$$
$$\left(\sqrt{\frac{q}{m}}\right)_{Be} = \sqrt{\frac{4}{9}} = 0.667$$

20 **Ans: D**

Comments

$E = IR_{total}$

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$6.0 = I \times (10 + 10)$
$I = 0.30\ A$
$Q = It$
$= 0.30 \times 60$
$= 18\ C$

21 Ans: **A**

Comments

Using potential divider rule,

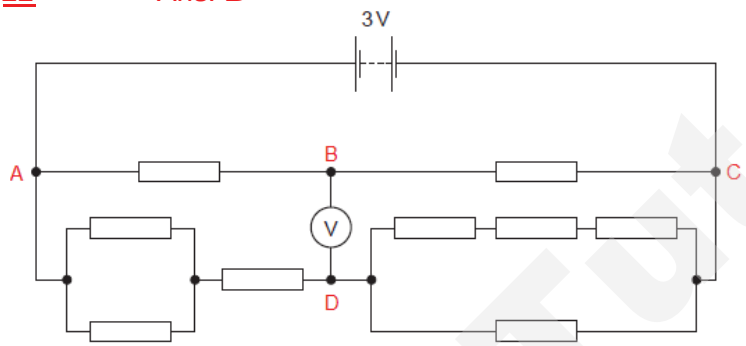
$$V = \frac{R}{R+r} \times E$$

Since r increases with E and R being constant, V decreases.

Thus, since $P_R = \frac{V^2}{R}$, output power also decreases.

22 Ans: **B**

Comments



$$R_{AD} = \left(\frac{1}{1000} + \frac{1}{1000}\right)^{-1} + 1000$$
$= 1500\ \Omega$

$$R_{DC} = \left(\frac{1}{1000+1000+1000} + \frac{1}{1000}\right)^{-1}$$
$= 750\ \Omega$

$$V_{BC} = \frac{R_{BC}}{R_{AB} + R_{BC}} \times E$$

$$V_{BC} = \frac{1000}{1000+1000} \times 3 = 1.5\ V$$

$$V_{DC} = \frac{R_{DC}}{R_{AD} + R_{DC}} \times E$$

$$V_{BC} = \frac{750}{1500+750} \times 3 = 1.0\ V$$

Voltage across the voltmeter
$V_{BD} = V_{BC} - V_{DC}$
$= 1.5 - 1.0 = 0.5\ V$

23 Ans: **D**

Comments

$$R = \frac{V}{I}$$

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Since R_Q is fixed, the ratio of its voltage and current is constant, i.e. the graph of its voltage and current is an upwards sloping straight line passing from the origin.

With resistors P and Q connected in series,
$E = I(R_P + R_Q)$
$= V_P + V_Q$
$V_P = E - V_Q$
Thus the variation with current of the voltmeter reading of P is a downwards sloping straight line.

24 Ans: **B** Comments

Using the Right Hand Grip rule,
- *the direction of resultant magnetic field caused by conductor P and R at the center is south west.*
- *the direction of magnetic field caused by conductor Q at the center is north west.*
- *Hence, (vectorially) adding the two magnetic field of equal magnitude, the direction of resultant magnetic field by all the conductors at the center is west of conductor S.*

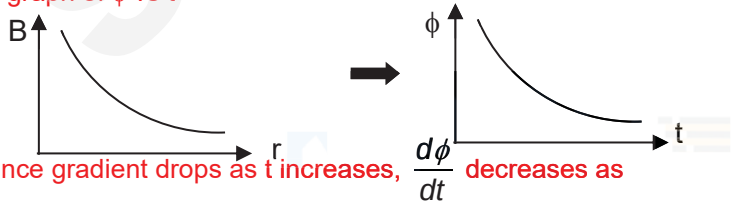
Using the Fleming's Left Hand rule, the direction of magnetic force acting on conductor S is south.

25 Ans: **D** Comments

According to Fleming's left hand rule, the positively-charged particle experiences a magnetic force that is perpendicular to its velocity and the magnetic field that it experiences. With magnetic field directed into the paper and current directed downwards, the magnetic force acting on the electrons is rightwards.

26 Ans: **A** Comments

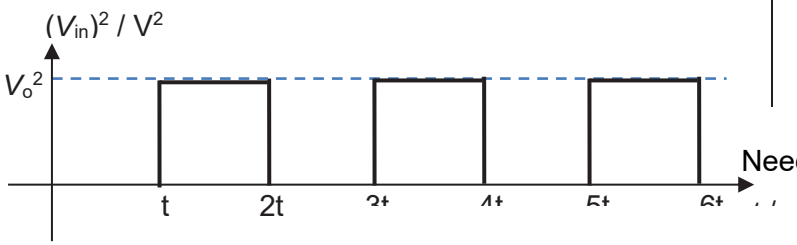
Since rod is moving at constant v, graph of B vs r will be similar to graph of ϕ vs t



Since gradient drops as t increases, $\frac{d\phi}{dt}$ decreases as conductor PQ moves away → magnitude of induced emf decreases.
Using FRHR, induced current is from Q to P, therefore P is at higher potential

27 Ans: **C** Comments

Half-wave rectification with the diode



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$$V_{rms} = \sqrt{\frac{{V_0}^2}{2}}$$

28 *Ans: **C***

Comments

The work function of a metal corresponds to the minimum photon energy required to eject photoelectrons from the metal surface. Hence since the work function of calcium is half that for platinum, the minimum photon energy to emit photoelectrons for calcium will be half that for platinum.

29 *Ans: **B***

Comments

Statement (i) is wrong. Most of the energy goes towards heating the metal target. Statement (ii) is wrong. "hc/E" is the minimum wavelength. Only statement (iii) is correct. The wavelengths of the characteristic X-ray spectral lines depend on the material used to make the target (and not the potential difference applied to accelerate the electrons).

30 *Ans: **C***

Comments

background count, B + radioactive source count, R = 120 – eqn (1)
After one half-life, R would be halved. $\Rightarrow$ B + ½R = 64 – eqn (2)
(1) – (2): ½R = 56 $\Rightarrow$ R = 112 counts
B + 112 = 120 $\Rightarrow$ B = 8 counts
When a 5 mm thick lead is inserted between the α-source and the detector, R = 0 (alpha radiation blocked by lead), therefore only the background count can be detected.

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1 (a)

An equation is homogeneous if every term in the equation has the same base units.

LHS: $[Q] = \text{kg s}^{-1}$

RHS: $\dfrac{[k][r^3][p_1 - p_2]}{[l]} = \dfrac{\text{m}^{-1}\ \text{s} \times \text{m}^3 \times \dfrac{\text{kg m s}^{-2}}{\text{m}^2}}{\text{m}}$ *[C1]*

$= \text{kg s}^{-1}$

Since the LHS and RHS of the equation has the same base units, the equation is homogeneous. *[A1]*

Comments

Many students did not explain the criteria when an equation would be homogeneous (When every term in the equation has the same base units). Many merely showed that LHS and RHS had the same units and stopped there, with no further explanation. Students must realize the importance of providing clear explanation for their conclusion.

Many students also did not use the [ ] correctly, failing to recognize that it means 'the unit of'.

1 (b)(i)

$v_y = u_y + a_y t$

$0 = 15.0 \sin 60° + (-9.81)t$ *[M1]*

$t = 1.33\ \text{s}$ *[A1]*

Comments

Quite well done

1 (b)(ii)

Since the ball travels through the same vertical height as it moves from the wall back to the ground, the time taken to travel from P to F = 1.33 s *[B1]*

$s_x = u_x t + \frac{1}{2} a_x t^2$

$6.15 = u_x \times 1.33 + \frac{1}{2} \times 0 \times 1.33^2$ *[M1]*

$u_x = 4.62 \approx 4.6\ \text{m s}^{-1}$ *[A0]*

Comments

Many students did not explain why the time taken for the ball to travel from ground to maximum height is the same as that taken to travel from the point of rebound back to the ground.

1 (b)(iii)

Change in momentum = Δmv

$= m(v_{rebound} - v_{incident})$

$= (60 \times 10^{-3})[4.6 - (-15\cos 60°)]$ *[M1]*

$= 0.73\ \text{N s}$ *OR* $-0.73\ \text{N s}$ *[A1]*

Comments

Many students failed to recognize that momentum is a vector quantity and hence since the incident velocity and rebound velocity are in opposite directions, the change would involve a vector subtraction rather than vector addition.

1 (b)(iii)

Since the rebound velocity (4.6 m s^{-1}) is less than the incident velocity (15 cos60° =7.5 ms^{-1}) OR relative speed of separation is less than relative speed of approach *[M1]*

Hence, collision is inelastic *[A1]*

Comments

A handful of students argued that the collision was inelastic because the momentum of the ball was not conserved. They were not given credit because conservation of momentum was not a necessary condition to determine if a collision is considered elastic or not. They must explain that the kinetic energy of the ball was not conserved instead.

2 (a)(i)

Since the gas is ideal, potential energy of the gas molecules is zero. Hence the internal energy is the sum of the random kinetic energies of the molecules.

Comments

Poorly done. While most students know that area under p-V graph gives the work done by gas and $\Delta U \propto \Delta T$, most equated ΔU = area under

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$\Delta U = \frac{3}{2} nR\Delta T$

For the process A → B, since the ideal gas undergoes expansion under constant pressure,

$p\Delta V = nR\Delta T$ *[M1]*

$\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} p\Delta V$

$= \frac{3}{2} \times 10.0 \times 10^5 \times 2.0 \times 10^{-4}$ *[M1]*

$= 300\ J$ *[A0]*

graph from V=0 to $V = 3.0 \times 10^{-4}$. This suggests a lack of understanding of the link between the area under the graph and ΔU .

2 (a)(ii)

Work done on the gas

= area under the graph = – p ($V_f - V_i$)

= – (10.0 × 10^5)(3.0 – 1.0) × 10^{-4}

= – 200 J *[M1]*

By first law of thermodynamics,

W + Q = ΔU

(- 200) + Q = 300 *[M1]*

Q = 500 J *[A1]*

Comments

Most students are able to get this right. For those who did not, many did not take into account the sign of W for expansion (which should be negative instead of positive).

2 (b)(i)

Since this is a cyclic process, the initial and final state of the cycle is the same [M1]. Hence the change in internal energy is zero [A1].

OR Since this is a cyclic process, the initial and final temperature of the ideal gas is the same [M1]. Hence the change in internal energy is zero [A1].

Comments

Only a handful managed to get the full credit. While most are able to recognise that ΔU = 0 for a cyclic process, they fall short of providing the correct explanation with the correct terms. Many only stated that the cycle goes back to the same "point" without elaborating the effect this has on the parameters (p, V and hence T) of the **initial** and **final states** of the gas.

2 (b)(ii)

	Q	W	ΔU
A → B	+	-	+
B → C	0	-	-
C → D	-	0	-
D → A	0	+	+

[1m for all correct W.D]
[1m for all correct Q]
[1m for all correct change in U]

Comments

Poorly done. Many did not know the effect on **Q** when expansion or compression is done "within a very short time". A handful were confused about the sign for W.

A to B: Since it is an expansion, W is negative. By first law of thermodynamics, given ΔU is positive and W is negative, Q needs to be positive.

B to C: Since it is an expansion, W is negative. Since it is an adiabatic process (according to the question), Q needs to be zero.

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C to D: Since there is no change in volume, W is zero. Since the pressure decrease at constant volume, temperature decrease, which means ΔU is negative. Thus Q also needs to be negative.
D to A: Since it is an compression, W is postive. Since it is an adiabatic process (according to the question), Q needs to be zero.

3 (a)
Principle of Superposition states that when two or more waves meet at a point [B1], the resultant displacement at that point is equal to the vector sum of the displacements due to the individual waves at that point [B1].

Comments
Some students who got this incorrect, mistaken the condition as the condition for stationary wave.

3 (b)(i)
Wave travel down the tube and gets reflected by the water [B1]. The incident and the reflected waves, both having the same amplitude, frequency (or wavelength) and speed travelling in opposite directions superpose [B1] to form standing wave.
OR
The incident sound wave travels along the tube and is reflected by the water. [B1]
The superposition of the incident and reflected wave of same amplitude, speed and wavelength(or frequency) but travelling in opposite directions [B1] creates a standing wave in the pipe.

Comments
Most students are able to identify that upon reflection, the reflected wave will have similar property as the incident wave. A handful of students did not apply the law of superposition after that. Also, A handful of students stated the condition for stationary wave to be formed generally without applying it to the question.

3 (b)(ii)
The length of the air column in tube will limit the type of stationary wave which can be formed within the air column as there is the boundary condition that it has to be a node formed at the closed end of the air column and a antinode at the open end of the air column. [B1] In general, the length of the air column L needs to be equal to $\lambda(2n+1)/4$ [B1], where λ is the wavelength of the incident wave and n is is an integer. If this condition is met, the loudness of the sound will be maximum, otherwise the sound will be of lower amplitude. [B1]

Comments
A lot of students failed to notice that the frequency and wavelength (hence the velocity) of the wave did not change and the change of the water level results in different harmonics

3 (b)(iii)
$\frac{1}{2}\lambda = 32.4\ cm = 0.324$ *[M1]*
$\lambda = 0.648\ m$
$v = f\lambda = 512 \times 0.648$
$= 332\ m\ s^{-1}$ *[A1]*

Comments
A handful of student identify the wrong wavelength

3 (b)(iv)
$\frac{1}{4}\lambda = L_1 + c$
$\frac{1}{4} \times 64.8 = 15.7 + c$
$c = +0.50\ cm$
Therefore the antinode is 0.50 cm above the top of the tube [A1] or 16.2 cm above the water surface due to end correction [A1].

Comments
A handful of student failed to use the value that is provided to pin point exactly the position of the antinode

4 (a)

Comments

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Electric field strength is the electric force per unit positive charge (on a small test charge) *[B1]*

Quite many students did not study their definition well, failing to highlight key considerations of "force PER UNIT charge" and "positive" charge.

4 (b)

$E = \frac{V_H - V_L}{d}$

$1.40 \times 10^4 = \frac{V_{btm} - 140}{0.015}$ *[C1]*

$V_{btm} = 350$ V *[A1]*

Comments

Quite a handful of students did not realize that the potential of the bottom plate must be higher than the top for the electric field to be pointing upwards.

4 (c)(i)

$F_n = ma$

$qE = ma$

$1.60 \times 10^{-19} \times 1.40 \times 10^4 = 9.11 \times 10^{-31} \times a$ *[C1]*

$a = 2.46 \times 10^{15}$ m s^{-2} *[A1]*

the direction of acceleration is towards the plate of higher potential or downwards *[B1]*

Comments

Quite well done in terms of calculation of the vertical acceleration of the electron within the electric field. However, many did not state the direction of a correctly, failing to recognize that the electron will be attracted downwards towards the plate of higher polarity.

4 (c)(ii)

$s_x = u_x t + \frac{1}{2} a_z t^2$

$0.120 = 5.0 \times 10^7 t + \frac{1}{2} \times 0 \times t^2$ *[C1]*

$t = 2.40 \times 10^{-9}$ s *[A1]*

Comments

Quite a handful of students failed to recognize that the horizontal acceleration of the electron was zero, but merely substituted the value of acceleration from 4(c)(i) into the horizontal displacement equation as shown.

4 (d)

Either

$s_y = u_y t + \frac{1}{2} a_y t^2$

$s_y = \left(0 \times 2.4 \times 10^{-9}\right) + \left(\frac{1}{2} \times 2.46 \times 10^{15} \times \left(2.4 \times 10^{-9}\right)^2\right)$ *[C1]*

$= 7.1 \times 10^{-3}$ m *[A1]*

Since 0.71 cm is less than 0.75 cm (distance away from the top plate), the electron does not hit the plates, thus passing between the plates. *[A1]*

Comments

Those students who got this part correct, provided a logical argument why the electron will pass between the plates and were given full credit. There were also a handful who did not use the correct approach in their reasoning.

Or

To hit the plate, the minimum vertical displacement = 0.75 cm

$0.75 \times 10^{-2} = \left(0 \times t\right) + \left(\frac{1}{2} \times 2.46 \times 10^{15} \times t^2\right)$ *[C1]*

$t = 2.47 \times 10^{-9}$ s *[A1]*

Since 2.47 ns is longer than the 2.4 ns, the electron does not hit the plates, thus passing between the plates. *[A1]*

5 (a)

For a length of wire l,

Total charge in volume V

Comments

Many are clueless how to start the derivation of current using the definition of current. For those who

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= number density of charge carrier × Volume × charge of each charge carriers

$= n \times Al \times q$ [M1]

Time taken for total charge to move through any cross section

$v = \frac{distance}{time} = \frac{l}{t}$

$t = \frac{l}{v}$ [M1]

Since $I = \frac{Q}{t}$

$I = \frac{nAlq}{\frac{l}{v}} = nAvq$ [A1]

5 (b)(i)

Since each copper atom contributes roughly one conduction electron, the number density of charge carriers is equal to the number of atoms per cubic metre.

$No\ of\ mol = \frac{Mass}{Molar\ Mass}$

Dividing both sides of the equation by volume:

$No\ of\ mol\ per\ unit\ volume = \frac{density}{Molar\ mass}$

$No\ of\ mol\ per\ unit\ volume = \frac{9000}{63.5 \times 10^{-3}} = 1.417 \times 10^{5}$ [M1]

$No\ of\ atom = No\ of\ mol \times N_A$

$No\ of\ atom\ per\ unit\ volume = No\ of\ mol\ per\ unit\ volume \times N_A$

number density = No of atom per unit volume

$= 1.417 \times 10^{5} \times 6.02 \times 10^{23}$ [M1]

$= 8.53 \times 10^{28} \approx 8.5 \times 10^{28}\ m^{-3}$ [A0]

5 (b)(ii)

$I = nAvq$

$17 \times 10^{-3} = 8.5 \times 10^{28} \times \frac{\pi}{4} \times \left(1.8 \times 10^{-3}\right)^2 \times v \times 1.6 \times 10^{-19}$ [C1]

$v = 4.91 \times 10^{-7}\ m\ s^{-1}$ [A1]

5 (b)(iii)

Current is the same in all segments of the wire, including the thinner wire [B1]. Having a smaller cross-sectional area, the electrons have to move at a higher drift velocity [B1].

5 (c)

Once the switch is closed, electric field is set up almost instantaneously OR all the electrons in the wire and filament to start to move together. [B1]

manage to derive, it is important show clear relationships between the variables, especially identifying the undefined variables.

Comments

Many did not show proper proof how the number density can be determined. There is a need to indicate correct variable, including stating the object of the variable (e.g. volume of 1 mole of atom)

Comments

Surprisingly, many did not attempt this part, indicating that they either did not read the question or they forget the equation of I = nAvq is provided in the formulae list.

Comments

Many wrongly focussed the argument on the resistance of the wire, without understanding that current in a "series" circuit is the same.

Comments

Many have the wrong idea that the electrons has very high instantaneous speed despite having small drift velocity.

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6 (a)

The decay constant of a radioactive material is the probability of decay of a nucleus per unit time [B1]. [B1]

Comments

Many could not give the correct definition for decay constant.

6 (b)

$\lambda = \frac{\ln 2}{87.7 \times 365 \times 24 \times 60 \times 60}$ [M1]

$= 2.51 \times 10^{-10}\ s^{-1}$ [A1]

Comments

Not well done. Many did not convert half-life to the appropriate unit. Some also did not know the conversion of unit of time from years to seconds.

6 (c)(i)

$A_0 = \lambda N_0$

$= 2.51 \times 10^{-10} \times 1.74 \times 10^{25}$ [M1]

$= 4.36 \times 10^{15}$ Bq [A1]

Comments

Fairly well done. Those who did not gain any credit clearly did not revise this topic as they could not give the correct formula for activity and number of nuclei.

6 (c)(ii)

$A = A_0 e^{-\lambda t}$

$= 4.36 \times 10^{15} \times e^{-2.51 \times 10^{-10} \times 10 \times 365 \times 24 \times 60 \times 60}$ [M1]

$= 4.03 \times 10^{15}$ Bq [A1]

Comments

Fairly well done. Many made conversion errors and some mistook the relation to be a positive rather than a negative exponential one.

7 (a)(i)

1. The engineer has to calculate to ensure that the beam is strong enough to withstand any forces applied to it.
2. He has to ensure that there is not too much sag in the beam for a given load.

Any of the above reasons [B1]

Comments

Well done. Students need to careful with language, making measurement cannot prevent the beam from collapsing. It is to ensure that beam is strong enough to take the load.

7 (a)(ii)

The reason is to minimise the amount of steel required for a given load. [B1]

Comments

Well done. Only a few students did not read the passage.

7 (a)(iii)

From the equation $x = \frac{WL^3}{kab^3}$, the amount of depression is inversely proportional to the width a and inversely proportionally to the cube of the depth b, for the same load and length. [M1] The diagram shows the beam B has a greater width a but a much smaller depth b. [M1] Since the effect of the depth has a larger impact on the depression compared to the width, hence beam B will sag more than beam C. [A1]

Comments

Poorly done. Students did not seem to realise that they are to use the equation to analyse this.

7 (b)

$x = \frac{WL^3}{kab^3}$

$0.010 = \frac{W \times 3.0^3}{3.6 \times 10^{10} \times 0.050 \times 0.10^3}$ [M1]

$W = 667$ N [A1]

Comments

There were several students who did not cube the length or the depth in their calculations. Students who showed the correct substitution and expression were awarded 1 mark.

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7 (c)(i)

When L = 1.750 m, x = 0.20 mm

$\log_{10}$ (L/m) = 0.2430 and $\log_{10}$ (x/mm) = 0.30 *[B1]*

Comments

Well done. Only a few students indicated the incorrect significant figures.

7 (c)(ii)

Plot the point to half a small square and draw a best-fit line for the graph. *[B1]*

Comments

There was some error in the plotting. Students should plot to half a small square and draw the best fit line.

7 (c)(iii)

Gradient = (0.980 – 0.180)/(0.470 – 0.200)

= 2.96

reading off to half the small square *[B1]*

Value within 2.85 – 3.15 *[A1]*

Comments

Some triangle used to calculate the gradient is too small. Some students incorrectly included 10^{-3} in the calculation.

7 (c)(iv)

$$\lg x = 3\lg L + \lg\left(\frac{W}{kab^3}\right)$$

The data yielded a linear graph for lg x versus lgL [B1 for working + statement]

The gradient of the graph was about 3, which tallies with the power of L in the relationship. [M1]

Hence the relation is true. *[A0]*

Comments

Students should indicate clearly that a straight line graph is obtained in the plot of log x vs log L.

Some students determined the percentage difference from the expected gradient of 3 and was awarded the mark in lieu of the straight line. Students should show the linearization clearly in their working.

7 (d)

Total moment

= (0.50)(10) + (1.3)(6.0) + (2.3)(22) + (3.1)(7.0) *[M1]*

= 8.51×10^4 N m *[A1]*

Comments

Generally well done.

7 (e)(i)

$$B = \frac{WL}{8}$$

$$= \frac{33000 \times 4.20}{8} = 1.73 \times 10^4 \text{ N m}$$ *[B1]*

Comments

Students are able to work out the value of B. There were several errors in the significant figures for this part.

7 (e)(ii)

$$x = \frac{BL^3}{c}$$

$$= \frac{1.7325 \times 10^4 \times 4.20^3}{3.35 \times 10^8}$$

= 0.00383 m *[B1]*

Comments

Generally well done.

7 (f)(i)

By interpolation,

$$\text{Stress} = \frac{83 - 93}{25 - 20} \times (21 - 20) + 93$$ *[M1]*

= 91 MPa *[A1]*

Comments

Students need to show their working clearly – in how they arrive at the value of the stress by interpolation. Students should observe that the value decreases with increasing *P*.

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7 (f)(ii)

$$\frac{\text{bending moment}}{\text{allowable bending stress}}$$

$$= \frac{17325}{91 \times 10^6} = 1.90 \times 10^{-4}\ m^3 \quad [M1]$$

Since the ratio is less than $2.0 \times 10^{-4}\ m^3$, the beam is safe [A1]

Comments

Most students who attempted this part were able to come to the correct conclusion.

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1 (a)(i)

By the principle of conservation of energy,

$$\frac{1}{2}Mv^2 = Mgh$$

$$v^2 = 2(9.81)(25) \quad [M1]$$

$$v = 22 \text{ or } 22.1 \text{ m s}^{-1} \quad [A1]$$

Comments

Quite well done. A handful of students used appropriate kinematics equations to solve which was accepted with full credit.

1 (a)(ii)

By the principle of conservation of momentum,

$$Mv = (M+m)v_{joint}$$

$$v_{joint} = \frac{(100)(22.15)}{(100+300)} \quad [M1]$$

$$v_{joint} = 5.54 \text{ m s}^{-1} \quad [A1]$$

Comments

Quite well done. However, quite a handful of students who got this wrong were careless in their substitution of mass of the pile and pile driver which were switched.

1 (b)(i)1.

Change in momentum $= p_f - p_i$

$$= \left[0 - (100+300)(5.54)\right] \quad [M1]$$

$$= -2220 \text{ kg ms}^{-1} \quad [A1]$$

Comments

Many students failed to recognize that momentum is a vector quantity and hence, since the final momentum of the pile and pile driver (as a joint body) was zero, the change of momentum would be a negative quantity.

1 (b)(i)2.

Area under the *F-t* graph = change in momentum

$$F_{ave}\Delta t = 2215 \quad [M1]$$

$$F_{ave} = \frac{2215}{0.18}$$

$$F_{ave} = 1.23 \text{ x } 10^4 \text{ N} \quad [A1]$$

Comments

Many students did not have the required concept of a 'constant' average force F_{ave} that will give an impulse equivalent to the 'area under the graph' provided in Fig. 1.2 or the change of momentum calculated in 1(b)(i)1. Hence, they had the impression that the F_{ave} asked for in this question is the maximum Force in Fig. 1.2 which is incorrect.

1 (b)(ii)

By the principle of conservation of energy,

KE Loss + GPE Loss = Work done against external resistive forces

$$\frac{1}{2}(M+m)v_{joint}^2 + (M+m)gd = F_{ave}(d)$$

$$\frac{1}{2}(400)(5.54)^2 + (400)(9.81)(d) = (1.23 \text{ x } 10^4)(d) \quad [M1]$$

d = 0.73 m [A1]

Comments

This part proved too difficult for most students. Many did not manage to get the correct answer and a majority of students did not consider the GPE lost of the pile and driver as it is lowered to a stop due the external resistive force.

2 (a)(i)

Radial lines (symmetrical) and pointing inwards *[B1]*

Comments

Students should draw straight lines with the use of ruler, else they will be penalised. Mostly well done, except for a few who drew concentric circles,

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likely because of confusion of magnetic field lines.

2 (a)(ii)

No difference in the pattern of the field lines for distance more than the radius of the initial sphere [B1] and the field lines are closer near the surface of smaller sphere. [B1]

Comments

Students should note that the number of field lines remain the same as the field strength for distance more than the radius of the initial sphere remains the same.

Many students went about explaining why the field strength is stronger. Students should look at the question stem. "Suggest" means students are to state the variation of the field lines they observe.

2 (b)(i)

$F_G = GMm/R^2$

$= (6.67 \times 10^{-11} \times 5.98 \times 10^{24})/ (6380 \times 10^3)^2$

$= 9.80$ N [A1]

Comments

Mostly well done. Students should pay attention to the conversion of units and the square in the separation.

2 (b)(ii)

$F_C = mR\omega^2$

$= (6380 \times 10^3)(2\pi/8.64 \times 10^3)^2$

$= 0.0337$ N [A1]

Comments

Mostly well done. Students should note that the quantities given are all to 3 s.f. and the final answer should be left to 3 s.f.

2 (b)(iii)

Difference in magnitude of the force = 9.77 N [A1]

Comments

Students who showed clearly the working are awarded the credit.

2 (c)

because acceleration (of free fall) is (resultant) force per unit mass, [B1]

Acceleration = 9.77 m s^{-2} [B1]

Note: An object, when falling, will also have the same angular velocity as an object on the surface of the Earth. Otherwise, the object will not fall vertically in a straight line. Thus the net force acting on the object is $F_g - F_c$.

Comments

Poorly done. Students need to show the explanation clearly. There were several students who simply use F = ma without explaining clearly that F refers to the net force which is equal to Fg – Fc. Students who indicated the unit of acceleration wrongly are penalised.

3 (a)

Total volume of molecules negligible compared to the volume of containing vessel

No intermolecular forces between the molecules

Molecules in random motion

Time of collision small compared with the time between collisions

Larger number of molecules

Any two

Comments

Mostly well-done. Students should realise the importance of comparison when they use the term "negligible". Also, there are some confusion between volume of gas, volume of gas molecules and volume of container. Some confusion also arises in the terms "time during collision" and "time between collisions"

3 (b)

In a real gas, there is a range of velocities or

Comments

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Must take the average of v^2 *[B1]*
Particles move in random direction and can move in x, y and z-direction. Since the proability is the same
$<v_x^2> = <v_y^2> = <v_z^2>$
$<c^2> = 1/3<v_x^2>$ *[B1]*

Most students did not mention clearly that there is a range of speeds in the x-direction. Students should read the question carefully and recognised that the question states that "all molecules move with speed v_x" which is physically inappropriate.
Most students recognise that that 1/3 factor is due to the random direction. However, students should note the difference in the terms "v_x^2" is different from $< v_x^2>$

3 (c)(i)
Nm = mass of gas
Therefore, density $\rho = M/V = Nm/V = nm$
Hence, $p = 1/3\ nm<c^2> = 1/3\ \rho<c^2>$ *[C1]*
$1.0 \times 105 = 1/3 \times 1.2 \times <c^2>$
$<c^2> = 2.5 \times 10^5$ *[C1]*
$C_{rms} = 500\ m\ s^{-1}$ *[A1]*

Comments
This part is poorly done. Students need to understand the terms in the equation and made reference to the original relationship.

3 (c)(ii)
$T \propto <c^2>$ *[C1]*
$<c^2> = 2.5 \times 10^5 \times 480/300$
$= 4.0 \times 10^5\ m^2\ s^{-2}$ *[A1]*

Comments
This part is poorly done. Most students do not know the relationship to apply to the question.

4 (a)
In a polarised wave, the vibrations of wave particles are limited to only one axis; whereas in an unpolarised wave there is no specific axis of vibrations or many different axis of vibrations.

Comments
The writing was not well done with many students mentioned that "waves travelled in multiple direction" and failed to identify that it is the vibrations that can take place in multiple or single axis.

4 (b)(i)
0 as no light will be able to pass through the polariser given it is perpendicular.

Comments
Well done.

4 (b)(ii)1.
$A_3 = A_2 \cos(62°-23°)$ [M1]
$A_2 = A_1 \cos(23°)$ [M1]
thus
$A_3 = A_1 \cos(27°) \cos(62°-27°)$
$= 0.715\ A_1$ [A0]

Comments
Well done with a handful of students not able to identify that when using **Malu's Law**, the angle required is the **angle between the axis of vibration and polariser**.

4 (b)(ii)2.
let the initial amplitude (unpolarised light) = A_0

$\frac{1}{2} = (\frac{A_1}{A_0})^2$
$A_0 = \sqrt{2}A_1 = 1.41\ A_1$ [C1]
$\frac{I_3}{I_0} = (\frac{A_3}{A_0})^2 = (\frac{0.715A_1}{\sqrt{2}A_1})^2 = 0.256$ [M1]

Comments
Common mistake was that students were confused with the different amplitude and intensity

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Percentage of intensity reduced = (1 - 0.256) x 100% = 74.4%
[A1]

5 (a)(i)
The waves generated by the sources have a phase difference that remains constant with time.
This can be achieved by connecting the two loudspeakers to the same sound source/ signal generator, producing waves that are in phase.
OR
two constant sound sources of the same frequencies.

Comments
Well done with a few students using the word same phase or in phase when explaining coherent.

5 (a)(ii)
The sound waves from the two sources undergo interference.
The path difference ($S_1P - S_2P$) and the phase difference at P is altering as S_1 moves.
Since the two sources are in phase, the waves meet in phase at P when the path difference between the sources is an integral multiple of wavelengths; constructive interference at P results in maximum intensity.
The waves meet in anti-phase at P when the path difference is an odd integral multiple of half wavelengths; destructive interference at P results in minimum intensity.

Comments
Generally, students showed an understanding of why there is interference but the reasoning may not be strong enough to get all the 3 marks

5 (a)(iii)

path difference = $S_1X = \frac{\lambda}{2}$;

λ = 0.164 m;

Comments
Well done with many students able to get the mark

5 (a)(iv)
S_1X = one wavelength = 0.082 m;
$v = f\lambda$ = 4100 x 0.082 = 336 m s^{-1} OR 340 m s^{-1};

Comments
Some students failed to identify the quantity of wavelength

5 (b)
During maxima, the resultant amplitude will the maximum vector sum of the amplitude of the 2 waves, while during minima,, the resultant amplitude will be the minimum vector sum of the two amplitude.
Thus in order to have the biggest contrast between these two vector sum, their amplitude have to be approximately the same.

Comments
Most students were able to see that with equal amplitude, there would be a complete destruction of waves during destructive interference but failed to explain the importance of it to be awarded the second mark.

6 (a)
Upward direction [B1]

Comments
A significant majority got it correct.

6 (b)(i)
For the negative particles to be undeviated,
Upward magnetic force = Downward electric force

$Bqv = qE$
$v = E / B$
$= (12 \times 10^3) / (930 \times 10^{-6})$ [M1]
$= 1.3 \times 10^7$ m s^{-1} [A1]

Comments
A significant majority got it correct. Most common error is to use concepts of circular motion which they had to assume that the negatively charged particle is an electron which is not mentioned till part (c).

6 (b)(ii)

Comments
Poorly done. Many are clueless how to attempt the question. Main error is to

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When a negative particle enter the magnetic field, the magnetic force on the particle provides for the centripetal force for it to move in a circular arc with radius *r*. [B1]

$Bqv = mv^2 / r$
$q / m = v / Br$
$= (1.3 \times 10^7) / (930 \times 10^{-6})(7.9 \times 10^{-2})$ [M1]
$= 1.8 \times 10^{11}$ C kg^{-1} [A1]

assume that the negatively charge particle is an electron which is not mentioned till part (c) where students simply divide its charge over mass.

6 (c)
The difference between alpha particle (helium nucleus) and electron is that the magnitude of the charge of alpha particle is 2 times that of the electron while the polarity of the charge of alpha particle and electron is positive and negative respectively.

As such, the difference in the magnitude of the charge of alpha particle causes the magnitude of both magnetic force and electric force acting on it to both be increased by 2 times. [B1]

The positive charge of the alpha particle causes the direction of the magnetic force and electric force to be now acting downwards and upwards respectively. [B1]6

Despite the changes, the resultant force remains zero. Hence the alpha particle still remains undeviated in the cross fields. [B1]

Comments
Poorly attempted. Students need to realise that the difference in the charge affects both the magnitude and direction of the magnetic and electric force in the cross fields. Many focus either on the effect on one force or one aspect (magnitude or direction) of the forces. It is insufficient to justify the undeviated path by stating the velocity remained the same with the same cross fields. It is also important to note that while it is true that there is a difference in mass between the two charges, the effect of gravitational force is negligible in this scenario.
$F_G = 6.55 \times 10^{-26}$ N
$F_E = F_B = 3.84 \times 10^{-15}$ N.

7 (a)(i)
Energy released in a reaction
$= (4(1.007825) - (4.002603 + 2(0.000549))u\ c^2$
$= 0.027599uc^2$ [M1]
$= 0.028697(1.66\times10^{-27})(3 \times 10^8)^2$
$= 4.1233 \times 10^{-12}$ J
$= 25.8$ MeV [A1]

Comments
Not well done. While many could compute the mass defect correctly, care was not taken in the conversion of units from u to kg. Many also overlooked the conversion of mass to energy when they omitted the product of c^2 in the computation of energy released. A handful was also unable to distinguish the conversion of J to eV and MeV.

7 (a)(ii)
Let the energy emitted out by the sun per unit time be E,

$$1.35\times10^3 = \frac{E}{4\pi(1.5\times10^{11})^2}$$ [M1]

$E = 3.817 \times 10^{26}$

Rate at which a hydrogen is converted
$= 4 [3.817 \times 10^{26} / 4.1233 \times 10^{-12}]$ [M1]
$= 3.70 \times 10^{38}$ [A1]

Comments
Poorly done. Many could not compute the rate of energy emission by the sun through the given intensity and distance from the source of emission. For those who were able to compute the rate of emission, many could not proceed to find the rate of hydrogen converted as they have failed to see the link in (i) and that for every reaction, 4 hydrogen nuclei are needed, hence the need to multiply 4 to the rate of reaction.

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7 (b)

Energy released in a nuclear reaction is equal to the difference in binding energies between the products and the original reactants. [B1] From graph, the steeper slope of the binding energy curve for lighter nuclei indicates that the change in binding energy in fusion is larger , compared to that for fission reactions. [B1] **larger change in B.E per nucleon for the same change in nucleon number.**

Comments

Poorly attempted. Many tried to explain the difference in energy released for fusion and fission reactions without referring to the graph even though it was explicitly stated in the question. Some could correctly identify that the difference in energy released is due to the difference in the steepness of the gradient, but most stopped short of elaborating how that leads to the conclusion that larger amount of energy is released for fusion than fission.

8 (a)(i)

The expression of restoring force in the form of y = kx suggests that with constant mass and spring shows that acceleration of the block is directly proportional to its displacement from its equilibrium position with constant gradient and no y-intercept [B1]

The negative gradient shows that its acceleration is always in the opposite direction to the displacement of the block. [B1]

Hence the features of the equation shows that the conditions of simple harmonic motion is satisfied.

Comments

Many simply state the 2 conditions needed for SHM. They failed to explain how the expression provide evidence for the two required conditions. In addition, the expression is in terms of resultant force, thus there is a need to relate how the resultant force is directly proportional to acceleration in the case of a constant mass.

8 (a)(ii)1.

The constant amplitude of the oscillations suggests that the oscillations are undamped. [B1]

Comments

Mostly correct. Main error is stating constant displacement instead of amplitude.

8 (a)(ii)2.

$\omega = \frac{2\pi}{T}$

$\omega = \frac{2\pi}{0.75}$ *[C1]*

$= 8.38 \text{ rad s}^{-1}$ *[A1]*

Comments

Significant majority got it correct. Some have difficulty reading off the correct period from the graph.

7 (a)(ii)3.

When KE = PE,

$\frac{1}{2}m\omega^2\left(x_0^2 - x^2\right) = \frac{1}{2}m\omega^2 x^2$ *[C1]*

$x_0^2 - x^2 = x^2$

$2x^2 = x_0^2$

$2x^2 = 0.020^2$ *[C1]*

$x = 0.0141$ m *[A1]*

Comments

Poorly attempted. Many did not know how to link KE and PE together with displacement as part of the expression. Many wrongly thought that PE only consists of GPE in a vertical oscillating spring-mass system, without considering EPE.

7 (b)(i)

Comments

Poorly attempted. Many failed to draw link between the displacement-time

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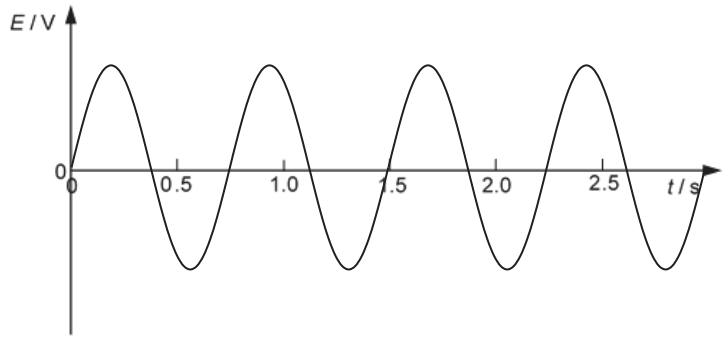

Shape of e.m.f. graph: sin or – sin function [B1]
Period of e.m.f. graph remains as 0.75 s [B1]

graph of the oscillation to the e.m.f.-time graph. This is clearly seen from b(ii). For those who manage to draw a sin or – sin graph, care is need to show constant period and amplitude. Some are poorly drawn.

7 (b)(ii)

When the magnet is placed near to the coil, its magnetic field is experienced by the coil. When it oscillates, the coil experienced a change of flux linkage, leading to an e.m.f. to be induced in it. According to Faraday's Law, this induced e.m.f. is proportional to the rate of change of magnetic flux linkage.

The velocity/speed of the magnet determines the rate of change of flux linkage [B1]. Since the motion of the magnet is simple harmonic, its velocity has a sinusoidal variation, the variation of the induced e.m.f. is also sinusoidal [B1]. Hence the induced e.m.f. is minimum when the magnet is at the amplitude positions (where velocity is zero) and maximum when the magnet is at the equilibrium positions (where velocity is at maximum) [B1].

Comments

Poorly attempted. Explanations for the shape of the curve were usually poor. Many did little more than give a statement of the laws of electromagnetic induction.

It is important to understand the shape of the graph requires the students to use Faraday's law to account for the **variation in the magnitude** of the e.m.f. Rarely was it made clear that the speed of the magnet determined the rate of change of flux linkage and hence the magnitude of the induced e.m.f. It is insufficient to either state that e.m.f. is induced (using Faraday's law) or account for the two polarities of the e.m.f. (using Lenz's law).

7 (c)(i)

As the magnet moves, flux Is cut by the coil, giving rise to induced e.m.f. in the coil [B1]. The induced e.m.f. gives rise to currents and heating of the coil [B1]. The thermal energy is derived from the oscillations of the magnet [B1]. Thus amplitude of the oscillation decreases. ***OR***

As the magnet moves, flux Is cut by the coil, giving rise to induced e.m.f. in the coil [B1]. The induced e.m.f. gives rise to currents which generate a magnetic field [B1]. The magnetic field opposes the motion of the magnet [B1]. Thus the amplitude of the oscillation decreases.

Comments

Poorly attempted. Similar to b(ii), many did little more than give a statement of the laws of electromagnetic induction. Another concern is that a significant no wrongly explain why the loss in the energy (instead of the oscillations of magnet in a solenoid connected to a **closed** circuit) lead to a decrease in amplitude in the first 10 oscillations.

7 (c)(ii)

$TE = \frac{1}{2} m\omega^2 x_0^2$

$\frac{TE}{0.80TE} = \frac{\frac{1}{2} m\omega^2 x_0^2}{\frac{1}{2} m\omega^2 x_0'^2}$ *[C1]*

$\frac{1}{0.80} = \frac{0.020^2}{x_0'^2}$

$x_0 = 0.0179$ m *[A1]*

Comments

Surprisingly, many do not know how to do this. Many wrongly thought that energy is directly proportional to amplitude instead of the correct relationship where the total energy is directly proportional to the square of the amplitude.

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7 (c)(iii)

When the resistance of the resistor is reduced, the induced current flowing in the resistor increases with the same e.m.f. induced [B1], leading to a higher rate of heat dissipated in the resistor [B1]. The amplitude of oscillation after 10 complete oscillations is reduced.

Comments

Many understand that the reduction in resistance would lead to an increase in current. However, it is important to highlight that the e.m.f. remain unchanged. The link between the increase in current to the decrease in amplitude of oscillation is often not clearly explained.

8 (a)(i)

hf : Energy of a (one) photon of frequency f incident on the metal surface

Φ : Work function of the metal surface

E_k :Maximum kinetic energy of a (one) photoelectron emitted from the metal surface

[B2]: All three correct

[B1]: Two of three correct

Comments

Majority were able to get one mark. Many did not recognise that the kinetic energy of the photoelectron is the maximum possible.

A handful also wrongly identified the kinetic energy as that of the photon and work function energy is the minimum energy required to emit a photon from the metal surface.

8 (a)(ii)

Conservation of Energy

By conservation of energy, the maximum kinetic energy of a photoelectron is equal to the energy gained by absorbing a photon, less the work done for it to escape from the metal surface. [B1]

Comments

Majority got it right.

A small handful however quoted the photoelectric effect equation which implied a lack of understanding of the objective of the question.

8 (a)(iii)1.

$$\frac{hc}{\lambda} = \phi + eV_s$$

$$\frac{(6.63\times10^{-34})(3.0\times10^{8})}{(300\times10^{-9})(1.6\times10^{-19})} = 2.03 + V_s \quad \text{[M1]}$$

$$V_s = 2.11\ \text{V}$$

[A1]

Comments

Not very well done. Many could not convert the energy term from eV to J and vice versa which led to many computational errors. A small handful also did not realise that in the computation of energy of photon using the wavelength, the corresponding unit is Joules and not eV.

8 (a)(iii)2.

Power of beam, P = (0.500)(4.5 x 10^{-5}) = 2.25 x 10^{-5} W

Number of incident photons per unit time, n_p

$$n_p = \frac{P\lambda}{hc} \quad \text{[M1]}$$

$$n_p = 3.39\times10^{13}\ \text{s}^{-1}$$

$$\text{Photoelectic Current } I = \frac{N_e e}{t}$$

$$= (5.70\times10^{-7} n_p)e \quad \text{[M1]}$$

$$= (5.70\times10^{-7})(3.39\times10^{13})(1.6\times10^{-19})$$

$$= \quad \text{A}$$

[A1]

Comments

A good number of students were able to get this right.

A handful of students mistook the rate of emission of photoelectrons as the current, failing to realise that current is the rate of flow of charges and not rate of emission of photoelectrons (charges).

8 (b)(i)

Comments

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Electrons have a wave-like nature. [B1]

Majority got this right.

8 (b)(ii)

Kinetic energy of electron at wall, E_k = 600 eV = 9.6 x 10^{-17} J [M1]

Momentum of electron at wall, p

$$p^2 = 2mE_k$$

$$p = \sqrt{2(9.11\times10^{-31})(9.6\times10^{-17})}$$ [M1]

$$= 1.32\times10^{-23} \text{ N s}$$

[A0]

Comments

Majority got this right.

8 (b)(iii)

de Broglie wavelength λ of electron at wall

$$= \frac{h}{p}$$

$$= \frac{6.63\times10^{-34}}{1.32\times10^{-23}}$$ [M1]

$$= 5.01\times10^{-11} \text{ m}$$

$$d = \frac{\lambda D}{a}$$

$$= \frac{(5.01\times10^{-11})(0.240)}{272\times10^{-9}}$$ [M1]

$$= 4.42\times10^{-5} \text{ m}$$

[A1]

Comments

A significant number of students while being able to compute the de Broglie wavelength, were unable to obtain the correct answer as they substituted the wrong value of slit separation, *a* which suggests the lack of understanding of what each term in the equation represents.

8 (c)(i)

Energy levels X can attain ≤ 12.8 – 13.6 = – 0.80 eV

Hence highest energy level that can be attained is – 0.85 eV [M1]

Number of wavelengths = number of discrete transitions

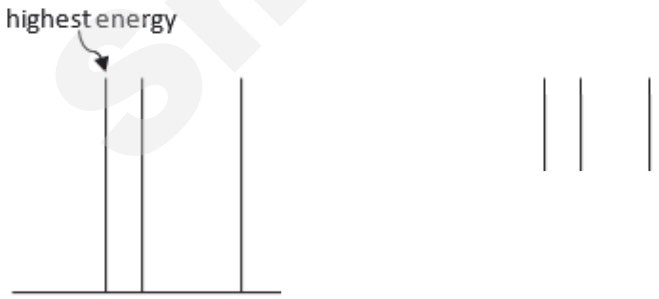
$= {}^4C_2$

= 6 [A1]

Comments

Very poorly attempted. Many did not know how to approach this question and did not recognise that the highest energy level must first be identified but the number of possible wavelengths could be computed.

8 (c)(ii)



- Correctly labels the highest energy line as the leftmost line
- 3 lowest and 3 highest wavelengths clustered as shown.
- Correct relative spacing between wavelengths within each cluster.

[B2] – All three shown

[B1] – Two of three shown

Note': ecf from (ii) can only be given if answer in (ii) is 10, corresponding to highest energy level attained is – 0.54 eV

Comments

Very poor attempted. Many did not label the "highest energy" even though it was stated in the question. Many displayed a lack of understanding of the concept behind transposing the energy level diagram to the spectral line diagram.

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8 (c)(iii)

Energy of highest energy photon
= – 0.85 – (–13.6)
= 12.75 eV = 2.04 x 10^{-18} J [M1]

$$E = \frac{hc}{\lambda}$$

$$2.04 \times 10^{-18} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{\lambda}$$ [M0]

$$\lambda = 97.5 \text{ nm}$$

[A1]

Comments

A good handful was able to get this right. Many did not recognise that the energy of the most energetic photon is 12.75 eV instead of 13.6 eV since the highest energy level is capped at -0.85 eV and not zero.

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JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	
CLASS	INDEX NUMBER

PHYSICS 9749/04

Paper 4 Practical

17 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Shift
Laboratory

IMPORTANT

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

The number of marks is given in the brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/14
2	/9
3	/20
4	/12
Penalty	
Total	/**55**
Percentage	

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Suggested solution

Question 1 (14 marks)

1 (a) (i) $L_1 = 28.0$ cm, $L_2 = 27.5$ cm

$L = 27.8$ cm **A1**: (check for L stated to the **nearest mm with unit**.)
(check for L stated in the range of **$26.0 \text{ cm} \leq L \leq 30.0 \text{ cm}$**)

(ii) $$\% \text{ uncertainty} = \frac{\Delta L}{L} \times 100\%$$
$$= (0.1 / 27.8) \times 100\%$$
$$= 0.36\ \%$$
A1: (check that **ΔL is 0.1 cm or 0.2 cm**)**(Not more than 0.2 cm)**
(check for **percentage uncertainty stated to 1 or 2 s.f.**)

(b) (i) $w = 2.00$ cm **A1**: (check for w stated to the **nearest 0.1 mm with unit**.)
(repeated reading required)
(check for w stated in the range of **$15.0 \text{ mm} \leq w \leq 25.0 \text{ mm}$**)

(ii)
$$A = L\,w$$
$$= (27.8)(2.00)$$
$$= 55.6 \text{ cm}^2$$
A1: (check for A stated to the **least s.f. of raw values with unit**.)(**allow ecf**)

(d) No. of oscillations: 15

t_1 / s	t_2 / s	T / s
15.64	15.76	1.047

$T = 1.047$ s

A1 - (check for raw values of t stated to **2 d.p. and more than 10 s**)
A2 - (check for **repeated readings** of t)
A3 – (check for T **correctly calculated** and stated to **correct 4 s.f. with unit**)

(e) New L measurement

$L_3 = 18.0$ cm, $L_4 = 18.0$ cm
$L = 18.0$ cm

(**A1**: check for measurement for L stated to the **nearest mm with unit**, **smaller value from L in (b)**)

New corresponding value of T

No. of oscillations: 15

t_1 / s	t_2 / s	T / s	T^2 / s^2
12.94	12.66	0.8533	0.7282

(**A2**: value of **second T <** value of **first T**). (Repeated readings for t not assessed here)
(**A3**: check for **T^2 correctly calculated** and **stated to correct s.f. with unit**)

Using the first data set, $L = 27.8$ cm and $T^2 = 1.096$ s^2,
$k = T^2 / L = 1.096 / 27.8 = 0.0394$ s^2 cm^{-1}

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Using the second data set, L = 18.0 cm and T^2 = 0.7282 s^2,
$k = T^2 / L$ = 0.7282 / 18.0 = 0.0405 s^2 cm^{-1}

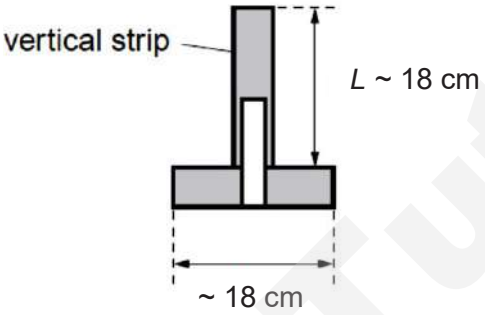
(**A4**: Correct **determination of constant of proportionality**)

Percentage difference = $\frac{0.0405-0.0394}{0.0394} \times 100\% = 2.8\ \%$

Since the percentage difference between the 2 proportionality constants is less than 10%, the suggestion of T^2 being proportional to L could be true.

(**A5**: **Drawing appropriate conclusion based on stated criterion of percentage difference** between the 2 constants of proportionality)

** Figure for second value of L (for reference only)



(f)

	1. Sources of error **(A1)**	**2.** Improvement **(A1)**	Do not credit
1	Two readings are not enough (to draw a conclusion)	Take more readings and plot a graph/calculate more k values (and compare)	
2	Card does not swing freely/ friction between pivot and card	Idea of using bushing or bearing.	
3	Difficult to judge end/start/a complete swing	Use of fiducial marker/pointer	Reaction time error/human reaction/difficult to know when to start/stop timer
4	Irregular/uneven/unusual swings/not in same vertical plane	Method of keeping shape aligned vertically in the same plane (elaborate)	
5	Oscillations die out quickly/ heavy damping	Use increased thickness of card / card that is more rigid	
6	Card is bent and will affect length measured	Use a more rigid card	

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Question 2 (9 marks)

2(a)(ii) m = 50 g **[M1 = 1]** (check for m stated to **g or kg with unit**.)
(Accept to the nearest 0.5 g)
(check for value of m in **range 45 g ≤ m ≤ 55 g**)

2(b)(iii) V = 5.270 V **[M2 = 1]** (check for V stated to **nearest mV with unit**)

2(c) θ_1 = 28.0 ^{0}C (check for θ_1 stated to the **nearest 0.5 ^{0}C with unit**.)

2(d)(ii) θ_2 = 31.0 ^{0}C **[M3 = 1]** (check for θ_2 stated to the **nearest 0.5 ^{0}C with unit**.)
(2(c) and 2(d)(ii) to be correct before awarding M3 mark)
($\theta_2 > \theta_1$)

2(d)(iii) ($\theta_2 - \theta_1$) = 3.0 ^{0}C **[M4 = 1]** (follow precision for θ_1 and θ_2 measurement)

2(e) $$V^2 = \frac{mcR}{t}(\theta_2 - \theta_1)$$

$$c = \frac{V^2 t}{mR(\theta_2 - \theta_1)}$$

$$c = \frac{(5.270)^2(4 \times 60)}{(0.050)(10)(3.0)}$$

c = 4400 J kg^{-1} K^{-1} **[M5 = 1]** (check for c stated correctly calculated to **4200 +/- 1000** with correct sf (**accept 1 more**)
[M6 = 1] (correct unit)

2(f) possible modifications are:

- Use heater with fins. This will increase the surface area of the heater in contact with water and hence improve the rate of heat transfer. **[M7 = 1]**
- Use a coiled heater with high number of turns. Similarly, there will be a larger surface area of the heater in contact with water. **[M8 = 1]**
- Increase the number of heater connected in parallel with the same power supply. This will decrease the effective resistance and increase the output power which in turn increase the rate of heat transfer. **[M9 = 1]**
- **Or any other acceptable method eg. (change material to one of lower specific heat capacity, colour the material black, using a cylindrical or spherical shaped heater)**

Note: Changes made to cover the beaker/ position of the heater are not acceptable as it does not change the design of the heater.

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Question 3 (20 marks)

3(a)(i) d_1 = 0.25 mm, d_2 = 0.25 mm
d = 0.25 mm **[M1 = 1]** (check for d stated to the **nearest 0.01 mm with unit**.)
(repeated readings needed)
(check for value of d in **range 0.15 mm ≤ d ≤ 0.44 mm**)

3(a)(ii) $A = \frac{\pi d^2}{4}$

$A = \frac{\pi\left(0.25 \text{ x } 10^{-3}\right)^2}{4}$

= 4.9 x 10^{-8} m^2 **[A1 = 1]** (check for A stated to the **correct sf of d with unit**)

3(b)(v) l = 0.300 m **[M2 = 1]** (check for l stated to the **nearest mm with unit**.)
(check for value of l in **range 0.100 m ≤ l ≤ 1.000 m**)

V = 0.804 V (check for V stated to the **nearest mV with unit**.)
(check for value of V in **range 0.500 V ≤ V ≤ 1.500 V**)

3(b)(vi) I = 48.6 mA **[M3 = 1]** (check for I stated to the **nearest 0.1 mA with unit**.)

3(c)(iv) l = 0.400 m **[no marks]**

V = 0.727 V

3(d)

l / m	V / V	$\frac{V}{l}$ / V m^{-1}	$\frac{1}{l}$ / m^{-1}
0.300	0.804	2.68	3.33
0.400	0.727	1.82	2.50
0.500	0.653	1.31	2.00
0.600	0.576	0.960	1.67
0.800	0.433	0.541	1.25
0.900	0.363	0.403	1.11

Table: (7 marks)

P1 - (Check for **correct column headers**)

M4 [2] - (Check for **minimum 6 sets** of data)

- Award **2 marks** if student has successfully collected **6 or more sets** of data (l,V) without assistance/intervention.
- Award **1 mark** if student has successfully collected **5 sets** of data (l,V) without assistance/intervention.
- Award **zero marks** if student has successfully collected **4 or fewer sets** of data (l,V) without assistance/intervention.
- **Deduct 1 mark** if student requires **some assistance/intervention** but has been able to do most of the work independently. Indicate the nature of any assistance.

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[Turn over

• **Deduct 2 marks** if student has been unable to collect data without **substantial assistance/intervention.**

Minimum mark for M4 = 0

P2 - (Check for correct precision for raw data l and V) – **nearest mm and nearest mV respectively**

P3 - (Check for range of l: **$\Delta l \geq 60$ cm**)

P4 - (Check for correct precision for calculated values of $\frac{V}{l}$ and $\frac{1}{l}$ (**least sf between V & l** and **sf of l respectively or one more**).

A2 - (Check for correctly calculated values of all calculated quantities. **Allow one slip**)

3(e) Linearize into - $[\frac{V}{l} = M\left(\frac{1}{l}\right) - N]$

Plot a graph of $\frac{V}{l}$ against $\left(\frac{1}{l}\right)$ with an expected gradient of M and a vertical intercept of $-N$.

A3 - (Check for **correct linearizing statement**)

3(e) Using points (1.00, 0.275) and (3.50, 2.850)

gradient = $(y_2 - y_1) / (x_2 - x_1)$
= [(2.850) – (0.275)] / [(3.50) – (1.00)]
= 1.03

M = 1.03 V (3 sf)

Substitute gradient and point (1.00, 0.275) into equation,

0.275 = 1.03(1.00) + *vertical intercept*
Vertical intercept = - 0.755

$-N = -0.755$
$N = 0.755$ V m^{-1} (3 sf)

A4 - (Check for **gradient triangle size greater than half the line drawn**. **Read-offs** must be **accurate to half a small square**. Gradient correctly calculated, **Δy/ Δx and not Δx/ Δy**)

A5 - (Check for **vertical intercept correctly read off to the nearest half small square OR calculated with a point on the line**)

A6 - (M = gradient calculated to **3 sf with correct units**)
(N = - intercept calculated to **3 sf with correct units**)

Graph: (3 marks)

P5 - (Check for **correct choice of scale and correct axis labels. Awkward scales not allowed**)(Only allow 1:1, 1:2, 1:2.5, 1:4, 1:5 and 1:10)

P6 - (**All observations** must be **plotted**. Check for **plotting accuracy to half a small square**. Check **points 2, 4 and 6** with increasing x-axis values)

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P7 - (Check for good choice of **best fit line**)

3(f) Most data points fall close to the best fit line and are randomly and equally distributed about the best fit line drawn. Hence, there are no anomalous points.

M4 - (Check for **correct comment**)(**Closeness to BFL** and **scatter** commented)
(Comment **must commensurate with the students plotted graph**)

3(g) $\rho = \frac{NA}{I}$

$\rho = \frac{(0.755)(4.9 \times 10^{-8})}{48.6 \times 10^{-3}}$

$\rho = 7.6 \times 10^{-7}\ \Omega\ m$

A7 - (Check for value of **ρ correctly calculated to the correct least sf of N, A and I**)
(Check for **ρ: $2.0 \times 10^{-7} <= \rho <= 20.0 \times 10^{-7}$ Ω m consistent with units**)

(Total: 20 marks)

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Question 4 (12 marks)

4

Diagram (1 × D1)

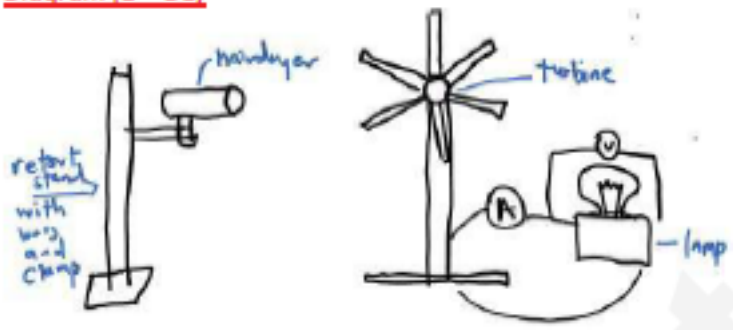

Diagram should show:

1. *the method to produce the air flow (e.g. fan, hair dryer, etc)*
2. *the method to determine the power of the lamp connected to turbine in closed circuit (e.g. ammeter and voltmeter)*

Procedure

(a) Set up the apparatus as shown above.

(b) Switch on the fan or hairdryer and close the switch of the circuit with the lamp.

Procedure and Measurement marks (1 × P1, 2 × M1)

(c) Measure the angle θ between the direction of the wind from the fan or hairdryer and the normal of the turbine using a protractor. *[M1]*

(d) Measure the current I through the lamp and the potential difference V across the lamp using an ammeter and voltmeter respectively. *[M1]*

(e) Repeat step (c) & (d) to obtain additional 6 sets of current and potential difference with different angles by rotating the turbine. *[P1]*

Analysis marks (3 × A1)

(f) The power of the lamp is determined by $P = IV$ ***[A1]***

(g) Plot a graph of P against $\cos\theta$ where k is the gradient of the best fitted line. *[A1]*

(h) The relationship is valid if the plotted points follows a straight line trend through the origin (y-intercept = 0) *[A1]*

Comments

In general, students need to be specific in their statements. More elaboration is given in the comments below.

Many are penalized when they did not show how the turbine is connected to lamp in series. There should not be any other electrical devices such as e.m.f. or resistor as these would affect the power of the lamp.

Students should identify the variable, the object and the instrument needed.
The power of the lamp should be measured directly rather than using LDR.

Students need to be specific in stating how the angle between the wind and the normal of the turbine **can be varied**.

Students should identify the symbol **used in the** determination of power of lamp.
The validity of the relationship is often missing. For those who try to answer this, they need to understand that this relationship is unique where the linearized trend is expected to pass through the origin since the y-

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intercept of the linearized equation is zero.

Control marks (2 × C1)

(i) Ensure that the speed of the wind/fan is the same (by applying the power or voltage of the fan the same or by monitoring it with an anemometer)

(j) Ensure that the distance between the fan/hairdryer and the turbine is the same (by measuring it with a metre rule before each reading).

(k) Ensure that the direction of the wind is the same (by using a wind vane)

The control variables identified should be focused on those that can affect the input power provided by the wind and the angle between the wind and normal of the turbine. Changes to the resistance of the lamp does not affect the power of the lamp since the current through lamp would react inversely.

Safety (1 × S1): moving turbine and hot lamp

- *Do not touch the turbine blades when it is moving*
- *Do not touch the hot lamp when it is operating for a period of time.*

It is important to highlight that the lamp would be only dangerously hot to touch when it is switched on for a period of time. The brightness of the lamp is usually not harmful to eyes.

Reliability (2 × R1)

To fix control variables

- *As stated above*

To measure independent variable accurately and precisely

- *Measure the direction of the wind accurately using a wind wave.*

To measure dependent variable accurately and precisely

- *Ensure that there is no other wind sources by doing the experiment in an enclosed room.*
- *The speed of the wind should be large so that the power of the lamp can be measurable.*
- *The turbine should have low friction so that there is minimal loss of power during the transfer of power between the turbine and the lamp.*
- *The readings should be taken only when the wind and/or meter readings have stabilized.*

Students need to focus on the key ideas on how to
1. fix the control variables
2. measure independent variable
3. measure dependent variable
in given context.

END OF PAPER

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JURONG JUNIOR COLLEGE
JC2 Preliminary Examination 2017

Name		Class	17S

PHYSICS **9749/1**
Higher 2

Multiple Choice **15 September 2017**
1 hour

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

(This question paper consists of 18 printed pages)

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$, $\quad v^2 = u^2 + 2as$
work done on/by a gas,	W	$= p\,\Delta V$
hydrostatic pressure,	p	$= \rho gh$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
temperature,	T/K	$= T/°C + 273.15$
pressure of an ideal gas,	p	$= \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	$= \frac{3}{2}kT$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
	v	$= \pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	$= Anvq$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	$= x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o n I$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{\ln 2}{t_{1/2}}$

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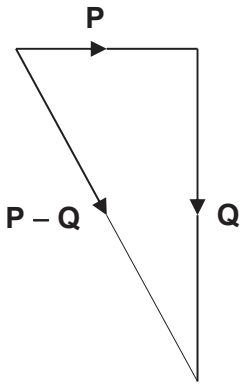
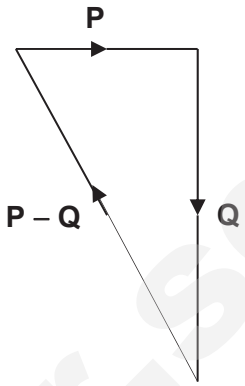
1 Which vector triangle shows the resultant of the vector subtraction **P** – **Q**?

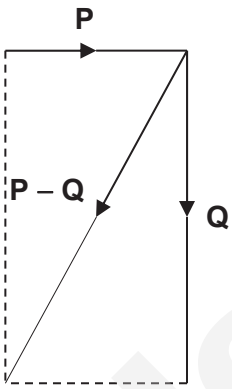
A



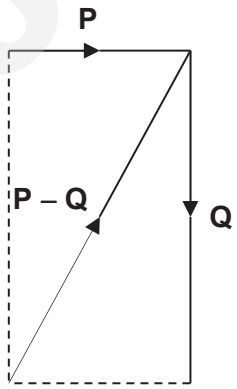
B



C



D



2 A crew of an oil tanker spotted an iceberg in its path and immediately sounded the alarm. At the time when the engine of the oil tanker was driven to slow it down, the oil tanker was moving at 10 m s^{-1}, the iceberg was 800 m away and moving at 0.5 m s^{-1} in the same direction as the oil tanker. The oil tanker managed to stop just 20 m from the iceberg.

Determine the average deceleration of the oil tanker.

A 0.055 m s^{-2}

B 0.058 m s^{-2}

C 0.067 m s^{-2}

D 0.071 m s^{-2}

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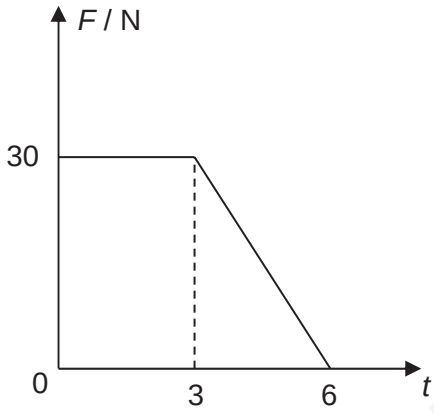
3 An object of mass 20 kg moves along a straight line on a smooth horizontal surface. A force F acts on the object in its direction of motion. The variation with time t of force F is shown.



What is the velocity of the object at t = 6 s if its velocity at t = 4 s is 4.5 m s^{-1}?

A 3.5 m s^{-1}

B 5.5 m s^{-1}

C 6.8 m s^{-1}

D 11 m s^{-1}

4 Rubber bullets, each of mass m, are fired at the rate of n bullets per second on a vertical wall. The speed of each bullet is u and they rebound from the wall with the same speed.

Determine the average force exerted on the wall.

A mnu

B $2mnu$

C $mnug$

D $2mnug$

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5 Blocks A and B have the same mass but different roughness. When block A is pulled with a force of 10 N, blocks A and B experience frictional forces of 4 N and 2 N respectively.



What is the tension in the rope joining blocks A and B?

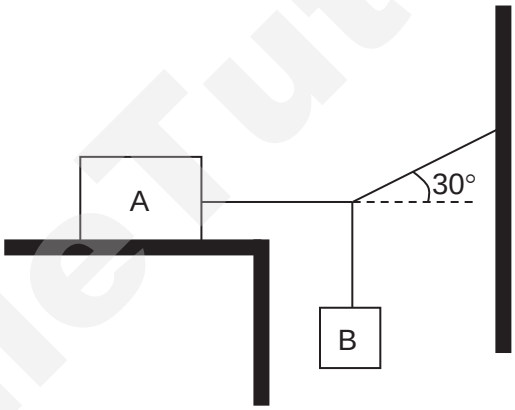
A 2 N

B 4 N

C 6 N

D 8 N

6 Inextensible strings hold blocks A and B in equilibrium as shown in the diagram. The static friction between block A and the rough horizontal surface is 1.8 N.



Determine the weight of block B.

A 0.90 N

B 1.0 N

C 1.6 N

D 3.1 N

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7 A small metal sphere of mass m moves through a viscous liquid.

When it reaches a constant downward velocity v, which of the following describes the changes with time in the kinetic energy and gravitational potential energy of the sphere?

	change in kinetic energy	**gravitational potential energy**
A	$\frac{1}{2}mv^2$	decreases at a rate of mgv
B	$\frac{1}{2}mv^2$	decreases at a rate of $(mgv - \frac{1}{2}mv^2)$
C	zero	decreases at a rate of $(\frac{1}{2}mv^2 - mgv)$
D	zero	decreases at a rate of mgv

8 One end of an inextensible string is attached to the handle of a pail of water. The other end is held by a student. The student swings the pail of water such that its trajectory is a circle in a vertical plane with a fixed centre (i.e. the hand that holds the string remains at the same position as it swings the pail of water in the vertical circle).

Which of the following statements is true?

A The velocity of the pail at the top is more than the velocity at the bottom.

B To keep the water in the pail at the top, the centripetal force must be greater than or equal to the weight of the water.

C The centripetal force acting on the pail of water at the top is due to the tension only.

D At the lowest point of the vertical circle, the weight of the water is balanced by the normal contact force acting on the water by the pail.

9 The acceleration of free fall at the surface of a distant planet was found to be equal to that at the surface of the Earth. If the diameter of the planet were twice the diameter of Earth, then the ratio of the mean density of the planet to that of Earth would be

A 1 : 2 **B** 1 : 4 **C** 2 : 1 **D** 4 : 1

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10 A fixed mass of ideal gas at a constant pressure of 2.0×10^4 Pa releases 1500 J of heat and as a result contracts from a volume of 0.050 m^3 to a volume of 0.025 m^3.

What is the change in its internal energy?

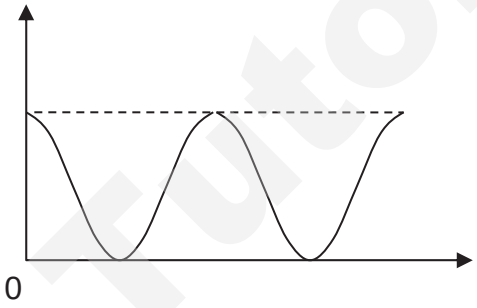
A decreases by 2000 J

B decreases by 1000 J

C increases by 1000 J

D increases by 2000 J

11 The diagram shows one possible graph for an object undergoing simple harmonic motion.



Which quantities could have been plotted to produce this graph?

A velocity vs displacement

B kinetic energy vs displacement

C potential energy vs time

D acceleration vs displacement

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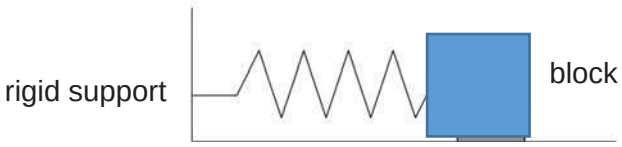
12 A wooden block is at rest on a horizontal frictionless surface. A horizontal spring is attached between the block and a rigid support.



The block is displaced to the right by an amount X and is then released. The period of oscillations is T and the total energy of the system is E.

For an initial displacement of $\frac{X}{2}$ which of the following is the best estimate for the period of oscillations and the total energy of the system?

	Period	Total energy
A	T	$\frac{E}{4}$
B	T	$\frac{E}{2}$
C	$\frac{T}{2}$	$\frac{E}{4}$
D	$\frac{T}{2}$	$\frac{E}{2}$

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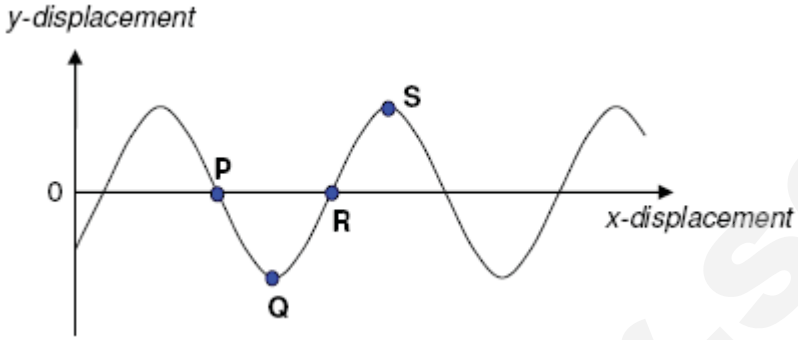
13 The graph below shows the profile of a progressive transverse wave at a particular instant of time. The waveform progress from left to right.

The particles **P**, **Q**, **R** and **S** all oscillate with uniform amplitude.



Which one of the following statements is correct?

A Particles P and R have zero kinetic energy.

B Particle P will move to the right after a while.

C Particles P and R are in anti-phase to each other.

D Particle S has the highest total energy.

14 A stationary sound wave has a series of nodes. The distance between the first and fourth node is 15.0 cm.

What is the wavelength of the sound wave?

A 4.0 cm

B 5.0 cm

C 10.0 cm

D 13.3 cm

15 Light of wavelength 650 nm passes through a slit 1.0×10^{-3} mm wide.

Determine how wide the central maximum is on a screen 30 cm away.

A 2.0×10^{-4} m

B 4.0×10^{-4} m

C 0.27 m

D 0.51 m

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16 A beam of white light was projected onto a diffraction grating with 400 lines per mm.

How many orders of the entire visible spectrum (400 nm – 700 nm) can it produce?

A 3 **B** 4 **C** 6 **D** 7

17 Which of the following statements about an electric field is incorrect?

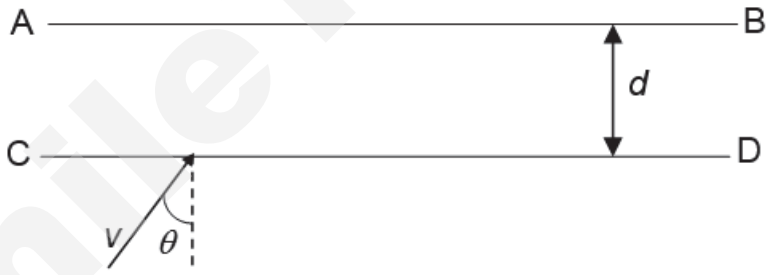
A The electric field strength at a point is a measure of the force exerted on a unit positive charge at that point.

B The electric field strength is zero at all points where the potential is zero.

C The electric field strength at a point is a measure of the potential gradient at that point.

D The electric field strength due to a point charge varies as $1/r^2$ where r is the distance from the charge.

18 The figure below shows two long parallel metal plates AB and CD in an evacuated enclosure. CD is maintained at a positive potential V relative to AB. Electrons of velocity v enter the space between the plates. The separation between the plates is d.



Given that the electron charge is $-e$ and the electron mass is m_e, the electrons will just reach AB if

A $\frac{1}{2}m_e(v\cos\theta)^2 = eV$.

B $\frac{1}{2}m_e(v\sin\theta)^2 = eV$.

C $\frac{1}{2}m_e v^2 = \frac{e}{4\pi\varepsilon_o d}$.

D $\frac{1}{2}m_e v^2 = eV$.

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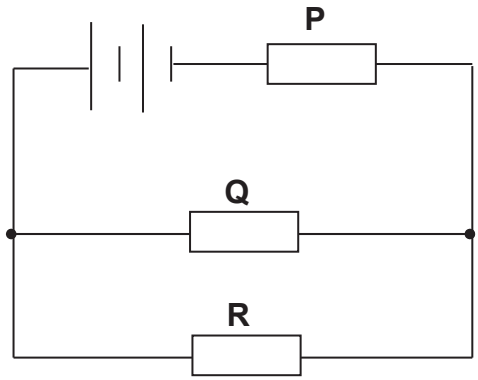
19 The resistors **P**, **Q** and **R** in the circuit shown below have equal resistance.



The battery, of negligible internal resistance, supplies a total power of 12 W.

What is the power dissipated in resistor **R**?

A 2.0 W **B** 3.0 W **C** 4.0 W **D** 6.0 W

20 In an electrostatic machine, a belt of width w, having surface charge density ρ, travels with velocity v. As the belt passes a certain point, all the charge is removed and is carried away as an electric current.

What is the magnitude of this current?

A ρwv

B ρwv^2

C $\frac{\rho w}{v}$

D $\frac{\rho v}{w}$

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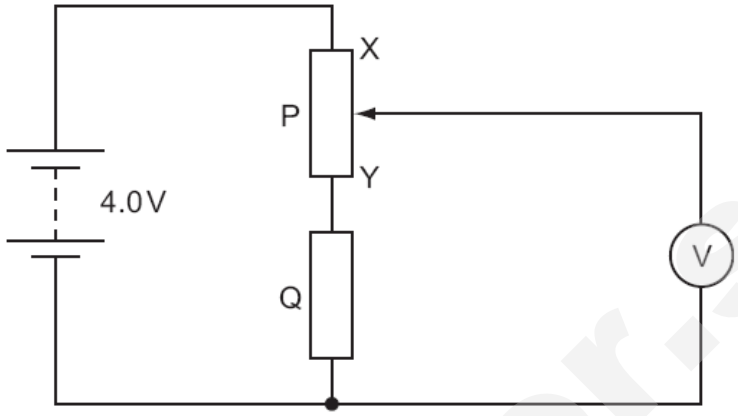
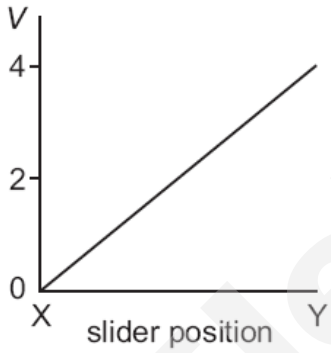
21 In the circuit below, P is a potentiometer of total resistance 10 Ω and Q is a fixed resistor of resistance 10 Ω. The battery has an e.m.f. of 4.0 V and negligible internal resistance. The voltmeter has a very high resistance. The slider on the potentiometer is moved from X to Y and a graph of voltmeter reading *V* is plotted against slider position.

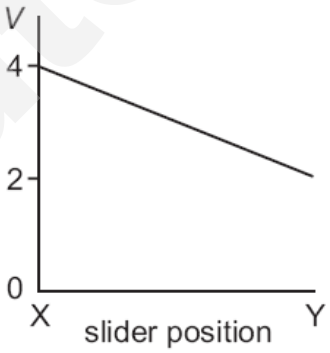


Which graph is obtained?

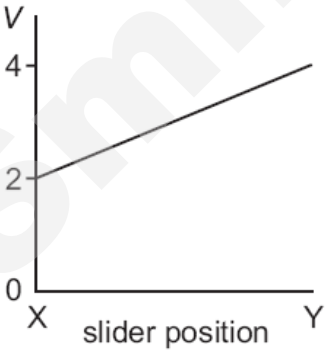
A



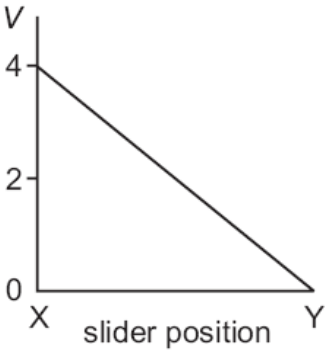
B



C



D



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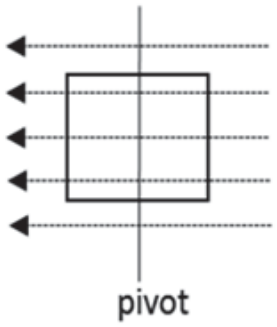
22 A 20-turns square coil of side 8.0 mm is pivoted at its centre and placed in a magnetic field of flux density 0.010 T. The two sides of the coil are parallel to the field and two sides of the coil are perpendicular to the field as shown below. A current of 5.0 mA is passed through the coil.



What is the magnitude of the torque acting on the square coil?

A 1.6×10^{-9} N m

B 3.2×10^{-8} N m

C 6.4×10^{-8} N m

D 3.2×10^{-5} N m

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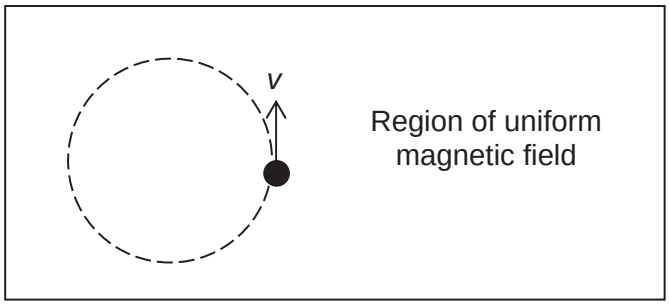
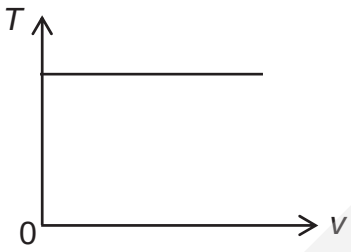
23 The figure below shows a charged particle projected with a speed v perpendicularly into a uniform magnetic field such that it moves in a circular path.

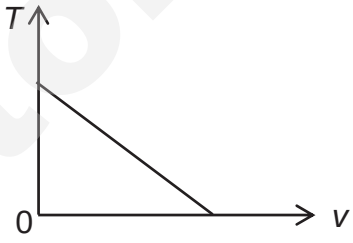


Which of the following represents the variation with v of its period T?

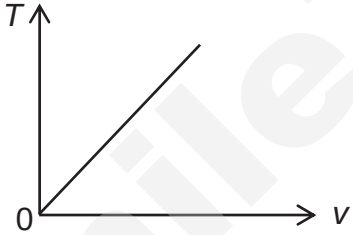
A



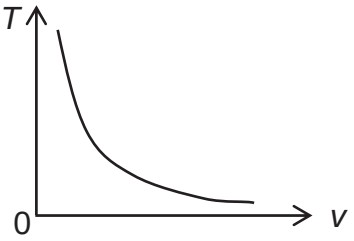
B



C



D



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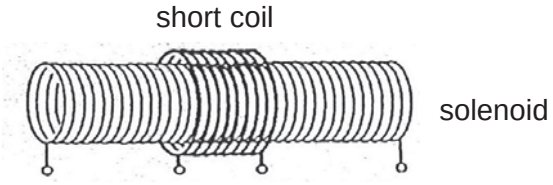
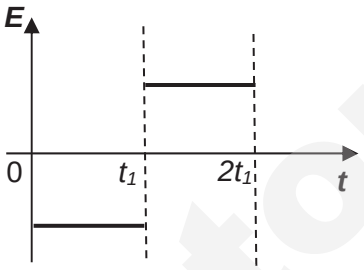
24 The figure shows a short coil wound over the middle part of a solenoid.

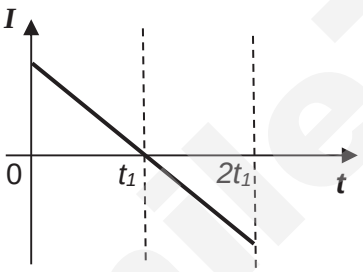


The variation of the e.m.f. E induced in the short coil with time t is as shown in the graph below.

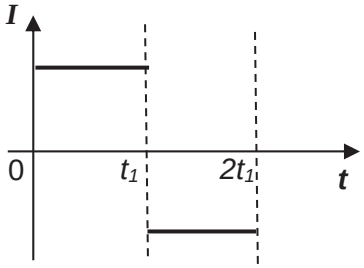


Which one of the following graphs best represents the variation of the current I in the solenoid with time?

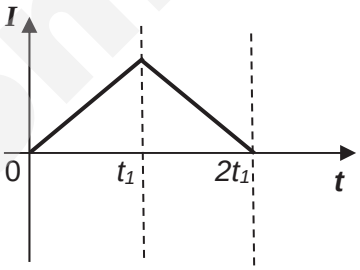
A



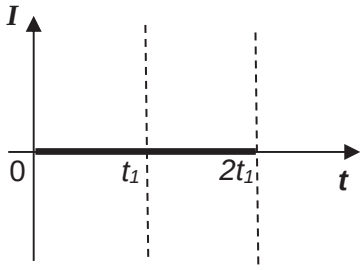
B



C



D



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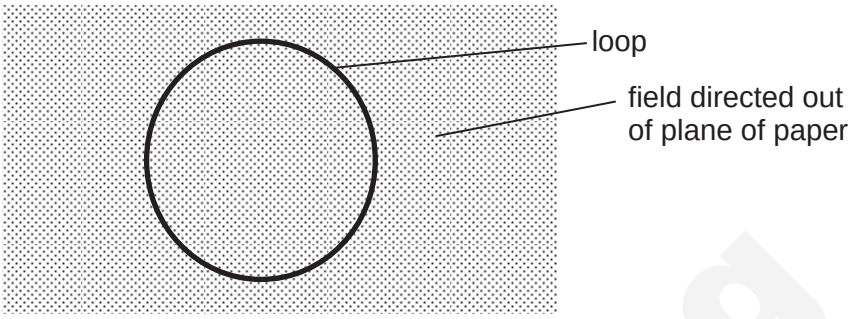
25 A uniform magnetic field is perpendicular to the plane of a loop of conducting wire.

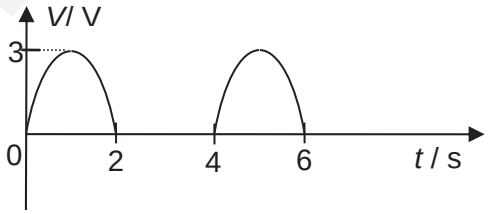


The field is directed out of the plane of paper. The magnitude of the magnetic flux density is decreasing at a constant rate.

Which of the following gives the correct state and correct direction of the induced current in the wire?

	Induced current	direction
A	varying	clockwise
B	constant	clockwise
C	varying	counter-clockwise
D	constant	counter-clockwise

26 The graph shows the variation with time *t* of the e.m.f. in a coil.



The resistance of the coil is 5.0 Ω. Which of the following is the average power dissipated in the coil?

A 0.45 W

B 0.90 W

C 1.5 W

D 2.1 W

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27 If the de Broglie waves associated with each of the following particles are to have the same wavelength, which particle must have the smallest velocity?

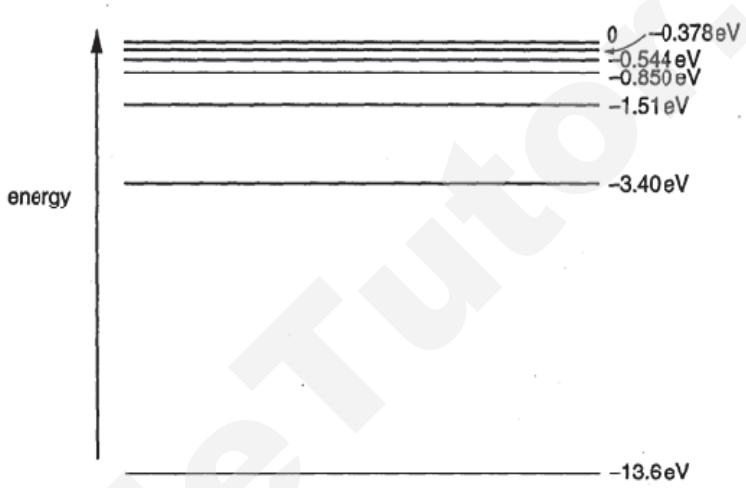
A proton

B electron

C neutron

D alpha particle

28 Some of the energy levels in atomic hydrogen are shown in the figure below.



Electrons having kinetic energy of 13.00 eV are incident on a sample of cold hydrogen gas.

Assume that the photon energies corresponding to wavelengths within the visible light spectrum are between 1.78 eV and 3.11 eV.

What is the maximum number of visible spectral lines that can be observed from the emission spectrum of the gas?

A zero **B** 2 **C** 3 **D** 6

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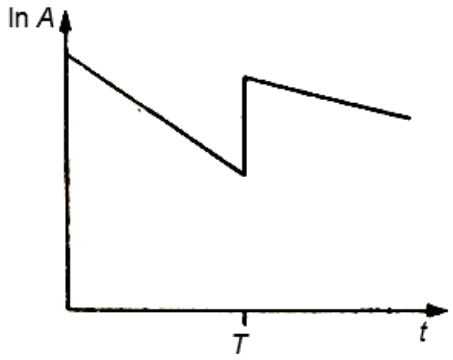
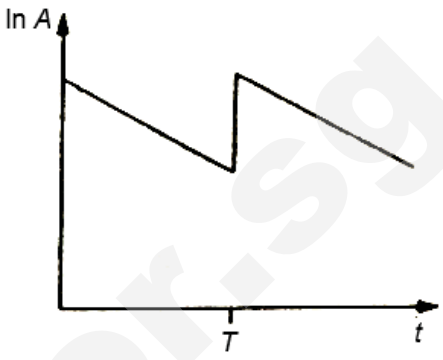
29 At time $t = 0$ some radioactive gas is injected into a sealed vessel. At time T some more of the same gas is injected into the same vessel.

Which one of the following graphs best represents the variation of the logarithm of the activity A of the gas with time t?

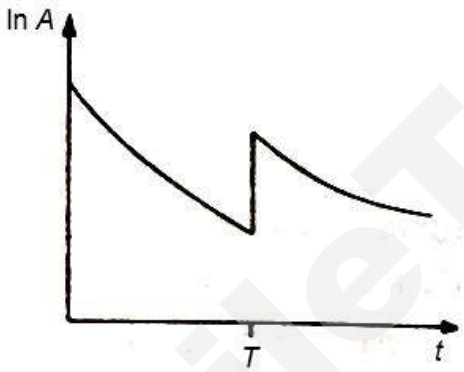
A



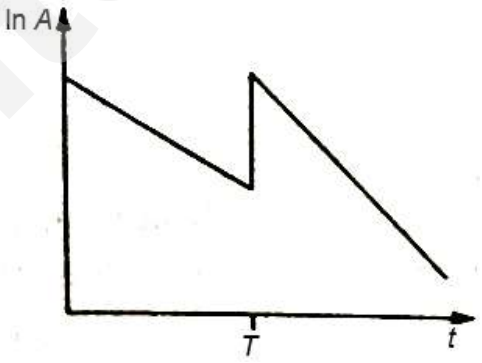
B



C



D



30 Radioactive ^{14}C dating was used to find the age of a wooden archeological specimen. Measurements were taken in three situations for which the following count rates were obtained:

specimen	*count rate*
1 g sample of living wood	80 counts per minute
1 g sample of archeological specimen	35 counts per minute
no sample	20 counts per minute

If the half-life of ^{14}C is known to be 5700 years, what was the approximate age of the archeological specimen?

A 2500 years

B 7000 years

C 11 000 years

D 13 000 years

End of Paper

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JURONG JUNIOR COLLEGE
JC2 Preliminary Examination 2017

Name		Class	17S

PHYSICS **9749/2**
Higher 2

Structured Questions **25 August 2017**
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

(This question paper consists of 22 printed pages)

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$, $\quad v^2 = u^2 + 2as$
work done on/by a gas,	W	$= p\,\Delta V$
hydrostatic pressure,	p	$= \rho gh$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
temperature,	T/K	$= T/°C + 273.15$
pressure of an ideal gas,	p	$= \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	$= \frac{3}{2}kT$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
	v	$= \pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	$= Anvq$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	$= x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o n I$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{\ln 2}{t_{1/2}}$

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1 Fig. 1 shows an experimental setup used to measure the acceleration of free fall.

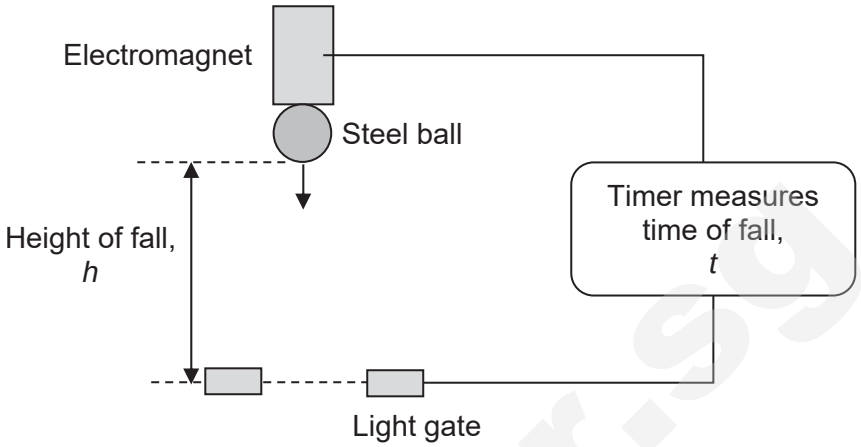

Fig. 1

The steel ball is suspended at the top by an electromagnet. The electronic timer starts when the electromagnet is turned off. As the steel ball falls by height h and goes through the light gate, the timer stops and displays the time of fall, t.

Only one set of data was collected:

$$h = (0.600 \pm 0.001)\ \text{m}$$

$$t = (354 \pm 1)\ \text{ms}$$

(a) Determine the acceleration of free fall with its associated uncertainty.

acceleration of free fall = ... ± ..... m s^{-2} [3]

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(b) It was later found out that when the electromagnet was turned off, there is some constant delay before the steel ball starts falling.

(i) Suggest a cause for this delay.

[1]

(ii) State and explain the type of error caused by this delay.

[2]

(iii) Suggest how this delay can be determined.

[2]

2 **(a)** Two objects, P and Q, of masses 1.5 kg and 0.30 kg respectively, are connected by a string that passes over a pulley as shown in Fig. 2.1. The pulley is frictionless and the string is inelastic. Object P rests on a horizontal hard surface.

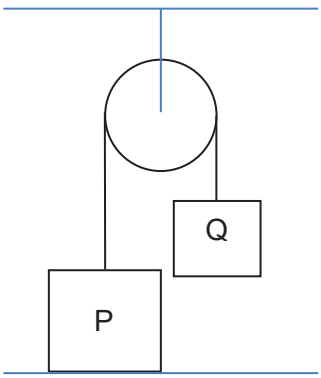

Fig. 2.1

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(i) Draw the forces acting on objects P and Q. [3]



(ii) Show that the contact force between the horizontal hard surface and object P is 12 N. [2]

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(b) The setup in **(a)** was modified such that object P floats horizontally in a fluid of density 1000 kg m^{-3}, with its lower face at a depth of 12 cm in the fluid, as shown in Fig. 2.2.

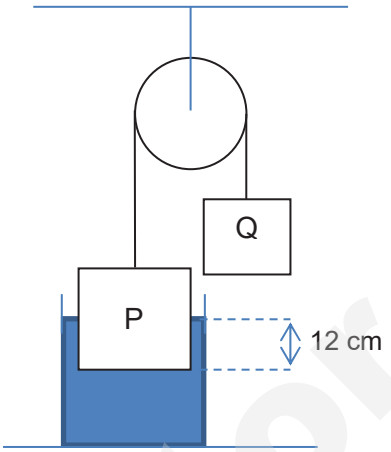

Fig. 2.2

(i) Explain what is meant by *upthrust*.

[1]

(ii) Determine the horizontal cross sectional area of object P.

horizontal cross sectional area = _____ m^2 [2]

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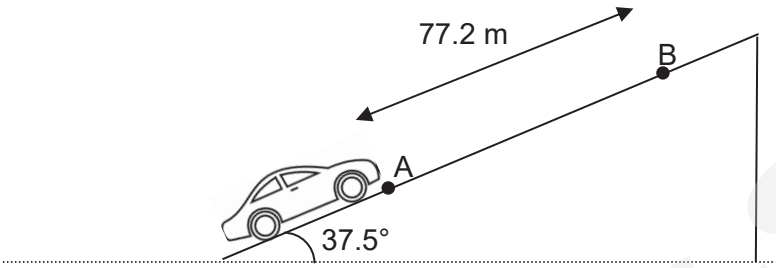
3 A drunk tourist at a ski resort drives his 1800 kg car up a snow-covered ski-jump at a constant speed of 60 km h^{-1} between points A and B as shown in Fig. 3. The ski-jump is inclined at an angle of 37.5° and points A and B are 77.2 m apart.



(Not drawn to scale)

Fig. 3

(a) Define *power*.

.....

.....

[1]

(b) Determine the minimum power required for the car to perform the feat.

minimum power = ... kW [3]

(c) At point B, a braking mechanism enables the car to be held at that position when it is stationary. If the braking mechanism suddenly fails and the car slides down the ski jump, calculate its speed when it reaches point A.

speed = ... m s^{-1} [2]

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4 Fig. 4 shows Graph A, which is the displacement-distance graph of a progressive transverse wave at time t = 0 s. Graph B represents the displacement-distance graph of the same wave at t = 0.1 s.

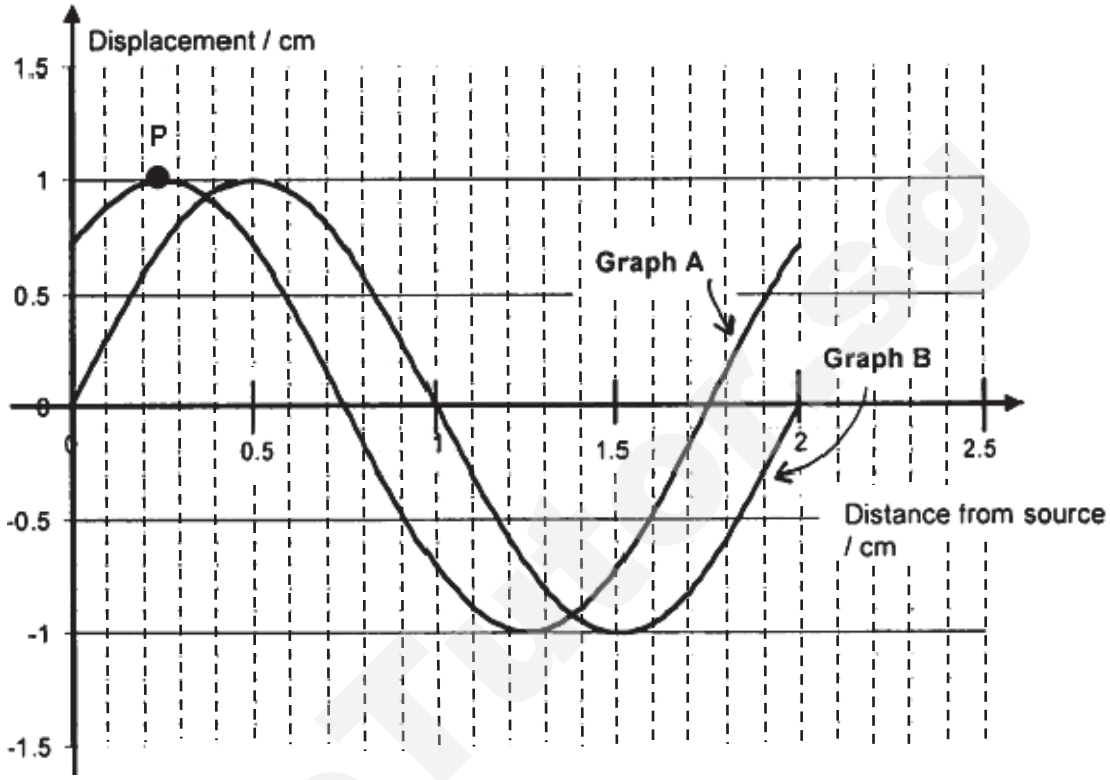

Fig 4

(a) Define *period* of a wave particle.

.....

.....

[1]

(b) State the wavelength of the progressive wave.

wavelength = ... m [1]

(c) A certain particle is at position P at time t = 0 s. On Graph B, draw a dot (labelling it **Q**), to represent the new position of this particle at t = 0.1 s. [1]

(d) Determine the phase difference between Graph A and Graph B.

phase difference = ... rad [2]

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(e) Determine the period of the wave.

period = ... s [2]

5 An old motor car travels at steady speed over a rough road on which the height varies in a sinusoidal way. The car's shock absorber mechanism which normally damps vertical oscillation is not working, and as a result, the car experiences rapid vertical oscillations.

Fig. 5 below shows the variation with vertical displacement x from the equilibrium position of the acceleration a, for the vertical motion of the car.

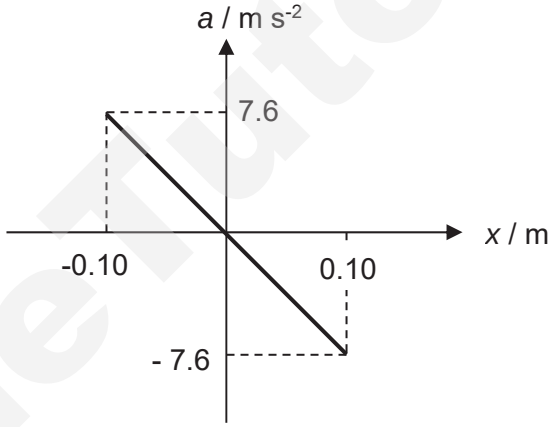

Fig. 5

(a) **(i)** Show that the angular frequency of the vertical oscillation is 8.7 rad s^{-1}. [2]

(ii) Hence, or otherwise, calculate the period of the vertical oscillation.

period = ... s [1]

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(b) **(i)** The car is at the lowest point of the vertical oscillation at t = 0 s.

Write down an equation to represent the variation with time t of the vertical displacement x from the equilibrium position, in terms of x, amplitude x_o, angular frequency ω and t. [1]

(ii) Determine the shortest time taken t for the car to oscillate from its lowest point to a point 0.025 m below its equilibrium position.

time = _____ s [2]

(c) If the car travels at a certain speed along this rough road, the vertical oscillations may become very large. Explain why this is so.

_____

_____

_____

_____ [2]

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6 Fig. 6 shows a wire frame ABCD supported on two knife-edges P and Q so that the section PBCQ of the frame lies within a solenoid. Side BC has a length of 5.0 cm and QC has a length of 12.0 cm.

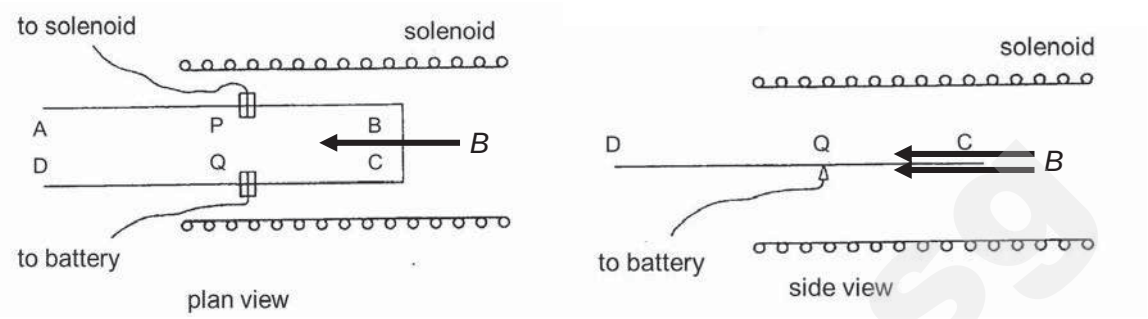

Fig. 6

Electrical connections are made to the frame through the knife-edges so that the part PBCQ of the frame and the solenoid can be connected in series with a battery. When there is no current in the circuit, the frame is horizontal.

(a) When the frame is horizontal and a current passes through both the frame and solenoid, the magnetic flux density *B* of the solenoid in the region of side BC of the frame is towards the left and the current flows from B to C.

State and explain the direction of the force, if any, due to the magnetic flux density *B* of the solenoid acting on

(i) side BC, and

[2]

(i) side AB.

[1]

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(b) **(i)** The solenoid has 700 turns m^{-1} and carries a current of 3.5 A.

Calculate the magnetic flux density B in the region of side BC of the frame.

magnetic flux density = _____ T [1]

(ii) Determine the force acting on BC due to the magnetic field in the solenoid.

force acting on BC = _____ N [2]

(iii) A small piece of paper of mass 0.100 g is placed on the side DQ and positioned so as to keep the frame horizontal.

Determine the distance d from the knife-edge the paper must be positioned.

distance d = _____ m [2]

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(iv) The current through both the solenoid and frame is doubled.

State and explain the changes, if any, that must be made to the mass of the piece of paper in order to keep the frame horizontal.

[2]

7 **(a)** Explain what is meant by the *half-life* of a nuclide.

[1]

(b) The decay of a radioactive nuclide may be represented by the equation

$$^{220}_{86}Rn \rightarrow Po + {}^{4}_{2}He$$

The binding energy per nucleon *E* for the three particles are given in Fig. 7.1 below.

particle	*E* / MeV
$^{220}_{86}Rn$	7.72
Po	7.76
$^{4}_{2}He$	6.51

Fig. 7.1

(i) Explain what is meant by the term *binding energy per nucleon* of a nucleus.

[1]

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(ii) Deduce values for the nucleon number and proton number of Po.

nucleon number = ...

proton number = ... [1]

(iii) Calculate the energy change in this nuclear reaction in joules.

energy change = ... J [3]

(iv) State and explain if the energy calculated in (iii) is released in or supplied to this reaction.

.....

.....

.....

.....

..... [3]

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(v) Sketch on Fig. 7.2, a labelled graph showing how the *binding energy per nucleon E* varies with *mass number*, indicating clearly:

1. the approximate positions of ${}^{2}_{1}H$, ${}^{56}_{26}Fe$ and ${}^{238}_{92}U$; and

2. the maximum value (in MeV) of the binding energy per nucleon.



Fig. 7.2

[3]

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8 Most man-made objects launched into space are satellites placed in a particular orbit around the Earth to function as TV transmitters, telephone relays or weather stations. Some spacecraft have been launched, however, to travel into much deeper space to explore the outer planets of our solar system. All spacecraft, whether satellites or deep space probes, must communicate with Earth by transmitting a radio signal.

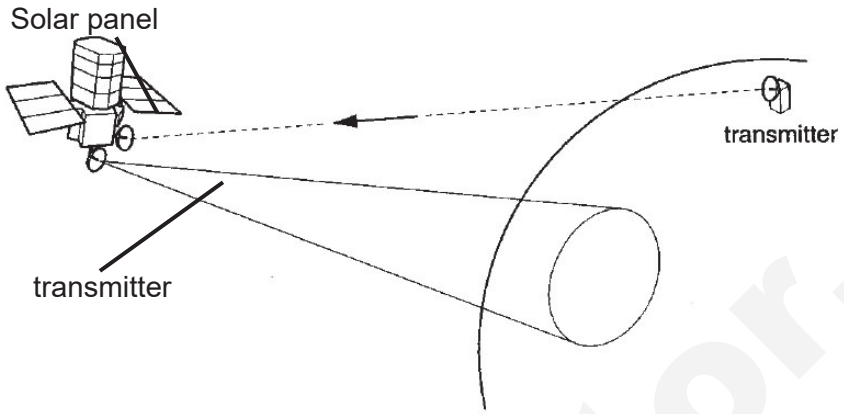

Fig. 8.1

The period and average orbital radius of three such satellites are given in the Fig. 8.2.

Satellite	Period T /h	Orbital radius R /km
A	1.63	7010
B	48.1	67100
C	57.2	75200

Fig. 8.2

(a) (i) Use data from Fig. 8.2 to show, without drawing a graph, that T^2 is proportional to R^3. [2]

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(ii) Use the data from Fig. 8.2, or otherwise, to calculate the orbital radius for a satellite with a period of 35.0 hours.

radius = _____ km [2]

(b) Most satellites in orbit around the Earth derive their power from a panel of solar cells which convert sunlight into electrical power. One such telecommunications satellite transmits a continuous 360 W signal powered from its battery for 24 hours per day. The battery is recharged from a solar panel which has an efficiency of 16% while in direct sunlight of light intensity 1.5 kW m^{-2}.

(i) Calculate the minimum surface area of solar panel required to produce the 360 W for the transmitter.

surface area = _____ m^2 [2]

(ii) Suggests two reason why the surface area would have to be much greater than your answer in (b)(i).

_____

_____

_____

[2]

(iii) For a spacecraft launched into the outer regions of the solar system, it is not practical to have its battery recharged by solar panels. State one reason why solar panels are not practical in deep space, that is, far away from the solar system.

_____

_____

[1]

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9 Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 9.1 have been used since 1870, particularly for pumping water on farms.

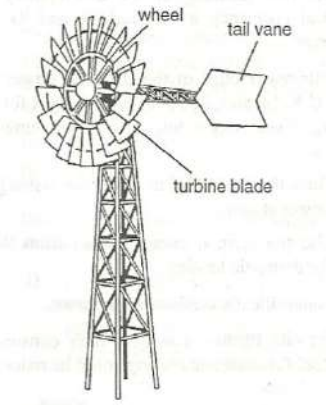

Fig. 9.1

The turbine blades cover almost the whole surface of the wheel and a tail vane behind the windmill keeps the wheel facing the wind. The diameters of the wheel of windmills of this type vary from 2 m to a practical maximum of about 12 m. Because of this size limitation, they are not suited to large power outputs. They will start freely with wind speeds as low as 2 m s^{-1} and, at these low speeds, can produce large torques.

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Fig. 9.2 shows how P, the output power of these windmills, varies with the overall diameter of the wheel for different wind speeds, v.

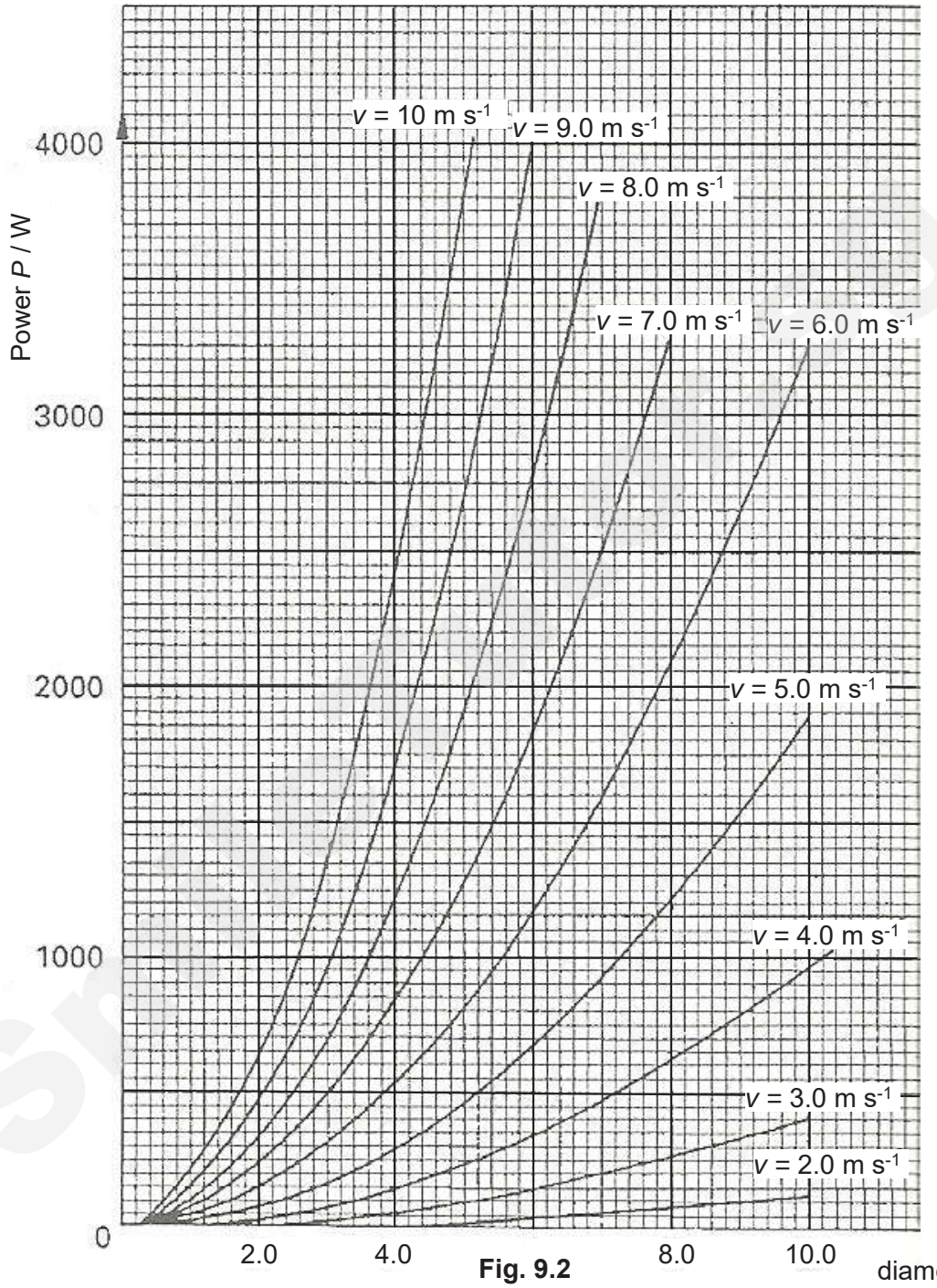

Fig. 9.2

It is thought that, for a given diameter, the output power is related to the wind speed by the equation

$$P = k v^{n},$$

where n and k are constants.

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(a) **(i)** Use Fig. 9.2 to determine lg (P / W) for a particular multi-bladed low-speed windmill with a wheel of diameter 6.0 m and wind speed 3.0 m s^{-1}.

lg (P / W) = _____ [1]

(ii) On Fig. 9.3,

1. Plot the point corresponding to a wheel diameter of 6.0 m and a wind speed of 3.0 m s^{-1},
2. Draw the line of best fit for the points.

[2]

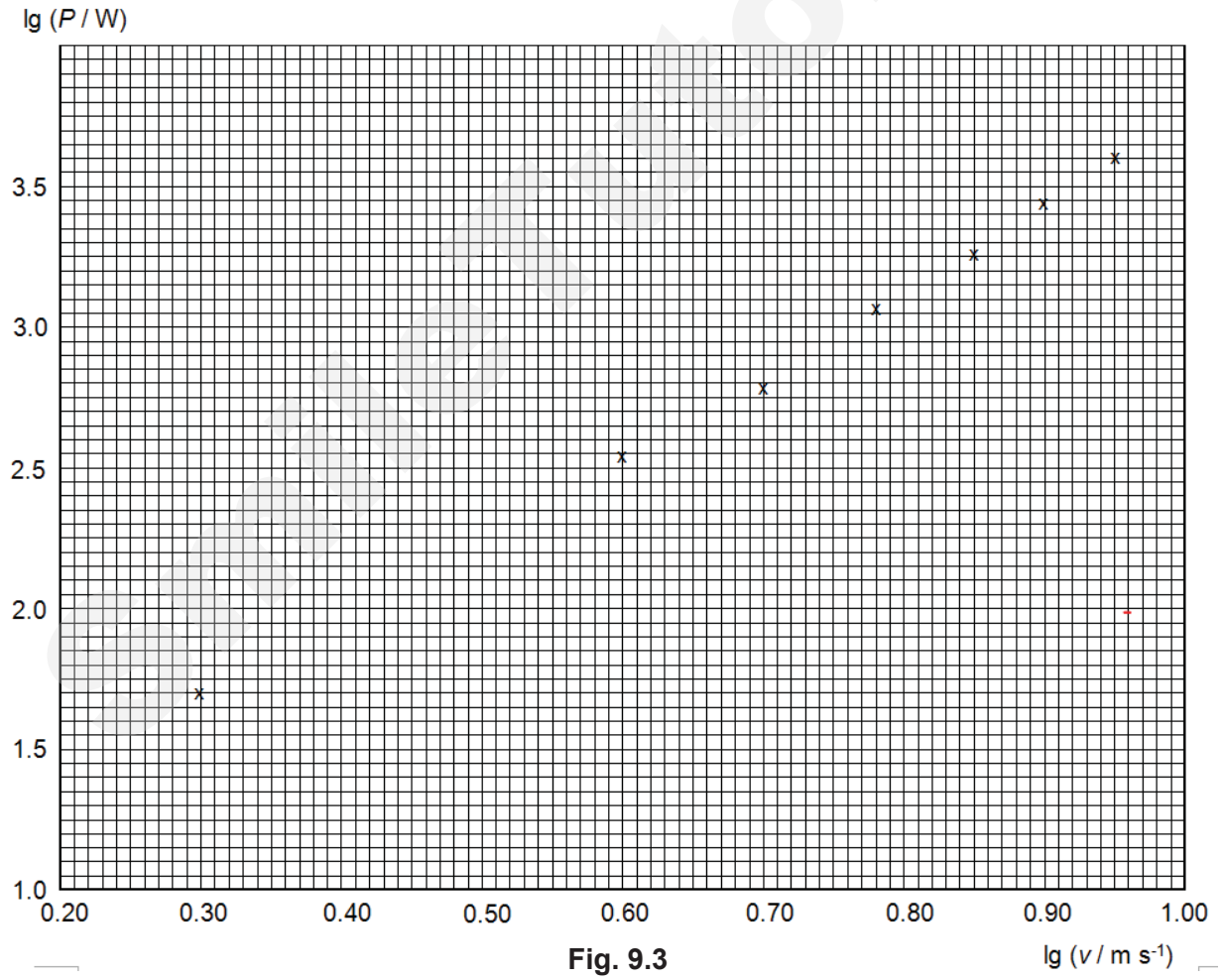

Fig. 9.3

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(iii) Use the line drawn in **(a)(ii)** to determine the magnitudes of the constants n and k in the expression given.

n = ...

k = ... [3]

(b) **(i)** When the wind speed is 8.0 m s^{-1}, calculate the volume of air that reaches the 6.0 m diameter wheel of the windmill in one second.

volume = ... m^3 [1]

(ii) The density of air is 1.3 kg m^{-3}. Calculate the kinetic energy of the volume of moving air in **(b)(i)**.

kinetic energy = ... J [2]

(c) Use your answer in **(b)(ii)**, together with data from Fig. 9.2 to find the fraction of this power converted into useful output power.

fraction = ... [1]

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(d) State one factor, other than wind speed and diameter of wheel, that is likely to influence the output power. In each case, indicate how the power output is likely to be affected.

.....

.....

[1]

(e) In practice, it has been found difficult to scale up a windmill such as this to a wheel of 30 m diameter, to achieve power outputs of the order of megawatts. Suggest one reason for this.

.....

.....

[1]

End of Paper

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JURONG JUNIOR COLLEGE
JC2 Preliminary Examination 2017

Name		Class	17S

PHYSICS **9749/03**

Higher 2

Longer Structured Questions **11 September 2017**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/10
2	/9
3	/10
4	/10
5	/11
6	/10
7	/20
8	/20
Total	/80

(This question paper consists of 21 printed pages)

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} $= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$, $\quad v^2 = u^2 + 2as$
work done on/by a gas,	W	$= p\,\Delta V$
hydrostatic pressure,	p	$= \rho g h$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
temperature,	T/K	$= T/°C + 273.15$
pressure of an ideal gas,	p	$= \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	$= \frac{3}{2}kT$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
	v	$= \pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	$= Anvq$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	$= x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o n I$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{\ln 2}{t_{1/2}}$

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Section A

Answer **all** the questions in this section.

1 Fig. 1.1 shows a smooth table on which there are two objects A and B of masses 1.5 kg and 5.0 kg respectively. Object B is initially stationary. Object A is moving to the right towards object B and hits it at a speed of 4.0 m s^{-1}. The collision is elastic.

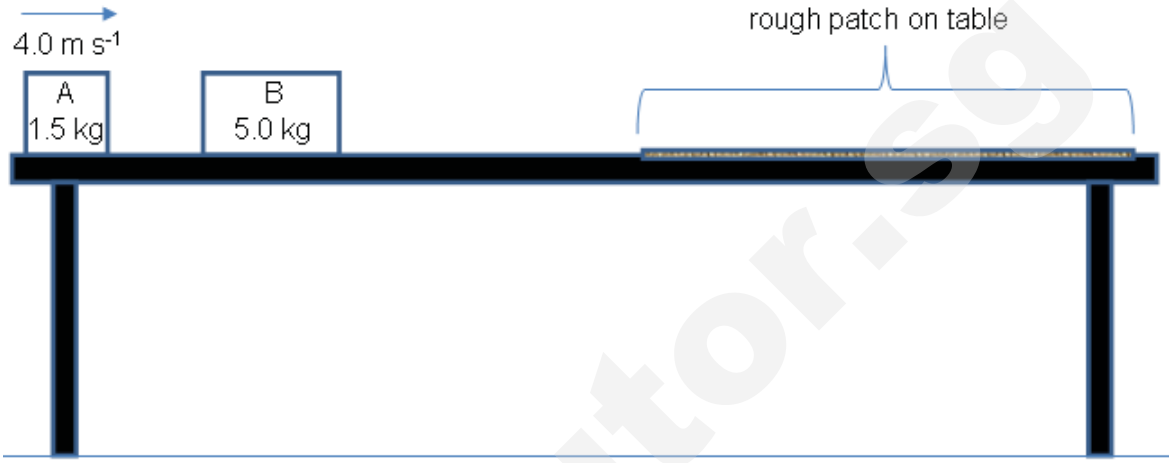

Fig. 1.1

(a) **(i)** State the principle of conservation of linear momentum.

.....

.....

[1]

(ii) Determine the final velocities of objects A and B after the collision.

final velocity of object A = ... m s^{-1} [2]

final velocity of object B = ... m s^{-1} [2]

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(b) After the collision, object B slides on the horizontal smooth table surface and then over the rough patch on the table before falling off the edge of the table with a horizontal velocity of 1.2 m s^{-1}. Object B lands in the middle of a sand bath whose top surface is 0.60 m below the top surface of the table as shown in Fig. 1.2. Assume air resistance is negligible.

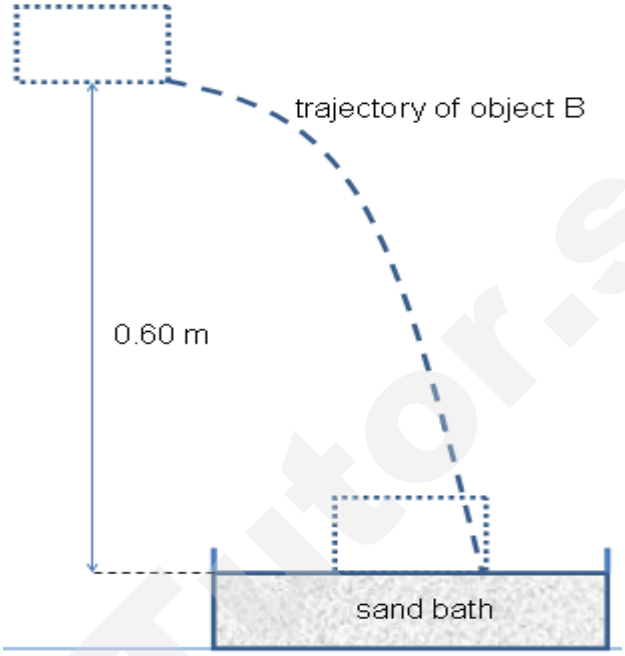

Fig. 1.2

Determine the horizontal distance from the edge of the table moved by object B when it just hits the sand bath.

horizontal distance = _____ m [3]

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(c) Object B is eventually embedded in the sand bath, entering vertically by 8.0 cm. Determine the magnitude of the average vertical retarding force.

magnitude of average vertical retarding force = ... N [2]

2 **(a)** Explain how molecular movement causes the pressure exerted by a gas on the walls of a container.

.....

.....

.....

.....

.....

.....

.....

[3]

(b) One mole of oxygen gas has a mass of 32 g. Assume oxygen behaves as an ideal gas at temperature 300 K and pressure 1.0×10^5 Pa. For this temperature and pressure,

(i) show that the volume of one mole of oxygen gas is 0.025 m^3, [1]

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(ii) calculate the density of oxygen gas,

density = _____ kg m^{-3} [1]

(iii) determine the root-mean-sqaure speed of the oxygen molecules,

root-mean-square speed = _____ m s^{-1} [2]

(iv) determine the average kinetic energy of the oxygen molecules.

average kinetic energy = _____ J [2]

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3 A student sets up the apparatus illustrated in Fig. 3.1 in order to observe two-source interference fringes. The double slit with slit separation 0.800 mm, situated 2.50 m from the screen, is illuminated with coherent red light of wavelength 690 nm. Fringes are observed on the screen.

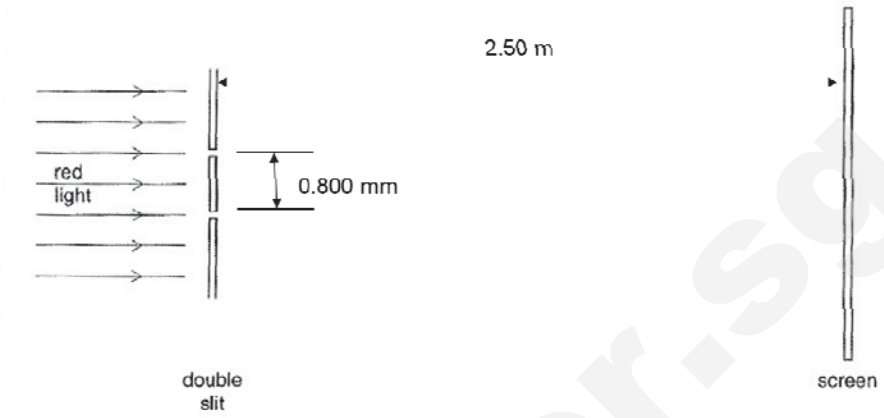

Fig 3.1

(a) Calculate the separation of the fringes.

separation = ... m [3]

(b) State and explain what change, if any, occurs in the separation of the fringes and in the contrast between bright and dark fringes observed on the screen, when each of the following changes is made separately.

(i) increasing the intensity of the red light incident on the double slit

.....

.....

.....

[2]

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(ii) increasing the distance between the double slit and the screen

[3]

(iii) changing the red light into green light

[2]

4 **(a)** The I-V characteristic of a 12 V car headlamp is drawn in Fig. 4.1. Only positive values of V and I are shown.

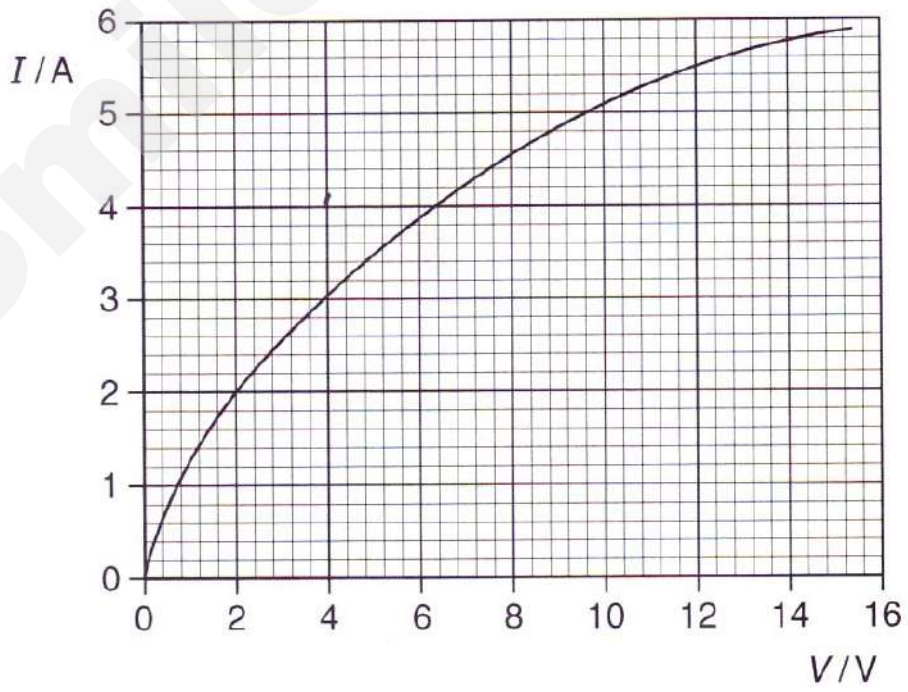

Fig. 4.1

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(i) Deduce the resistance of the headlamp at 2 V and 10 V.

resistance at 2 V = _____ Ω

resistance at 10 V = _____ Ω [3]

(ii) Explain in terms of the movement of charged particles why the resistance increases with potential difference as shown in Fig. 4.1.

_____

_____

_____

_____ [2]

(b) The filament of a headlamp could be manufactured from a straight piece of tungsten wire of diameter 0.084 mm.

(i) Calculate the length of wire required for a resistance of 0.50 Ω when the wire is at room temperature. The resistivity of tungsten at room temperature is 5.5×10^{-8} Ω m.

length = _____ m [4]

(ii) Explain why this straight length of wire is not practical.

_____

_____ [1]

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5 **(a)** Define *electric field strength*.

[1]

(b) Two charged solid metal spheres A and B are situated in a vacuum. Their centres are separated by a distance of 12.0 cm, as illustrated in Fig. 5.1. The diagram is not drawn to scale.

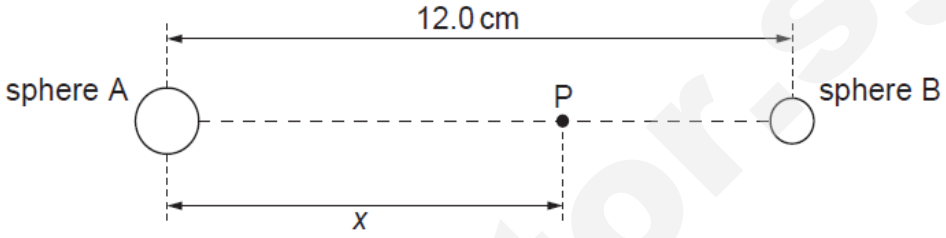

Fig. 5.1

Point P is a point on the line joining the centres of the two spheres. Point P is a distance *x* from the centre of sphere A.

The variation with distance *x* of the electric field strength *E* at point P is shown in Fig. 5.2. A positive value of *E* on the graph at a point corresponds to an electric field vector pointing horizontally to the right.

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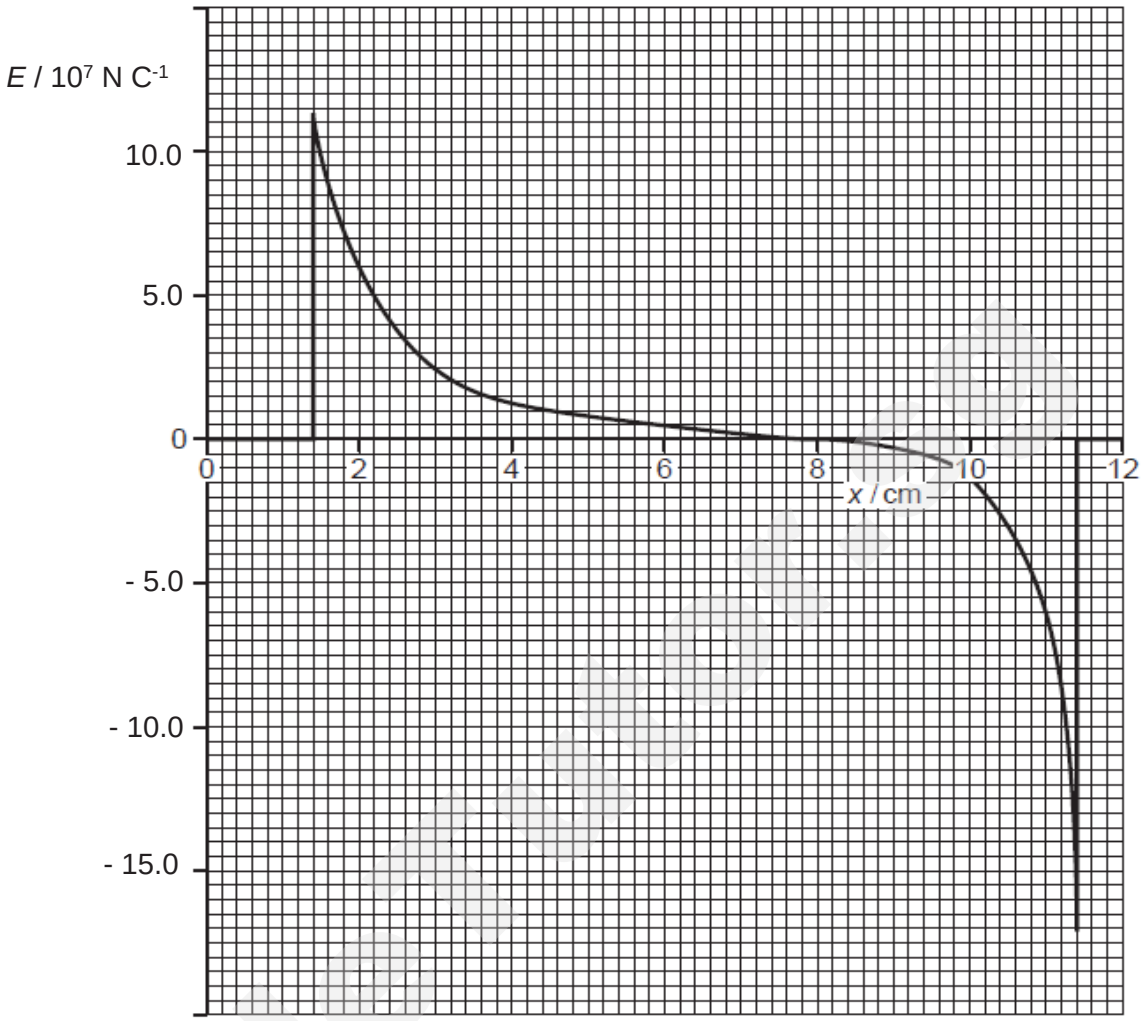

Fig. 5.2

(i) State and explain

1. whether the charge of sphere B is positive or negative,

[1]

2. the variation of electric potential within spheres A and B.

[2]

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(ii) The ratio of the magnitude of the charges of spheres A and B respectively is 4:1.

If the electric field strength at x = 4.0 cm is 1.25×10^7 N C^{-1}, calculate the numerical value of the charge of sphere B.

charge of sphere B = _____ C [3]

(iii) A proton moves along the line joining the centres of the two spheres.

Estimate the energy gained by this proton as it moves from the point where x = 3.0 cm to the point where x = 1.4 cm.

energy = _____ J [4]

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6 **(a)** With reference to the photoelectric effect, state what is meant by *work function* of a metal.

[1]

(b) In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface and the maximum kinetic energy E_{max} of the emitted electrons. The variation with E_{max} of λ is shown in Fig. 6.

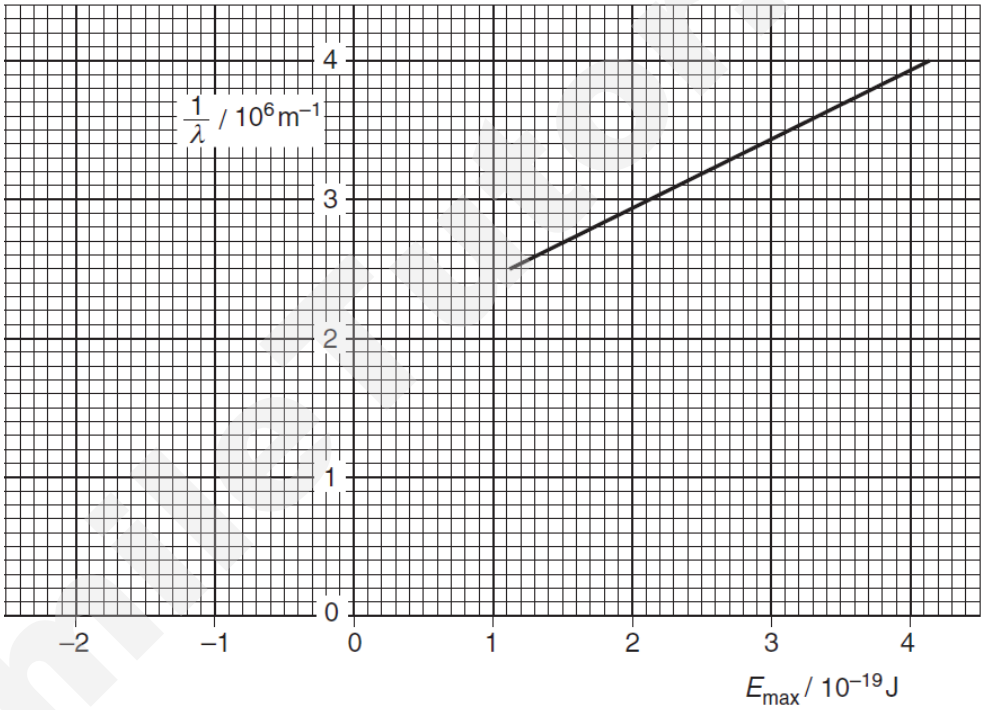

Fig. 6

(i) State an equation, in terms of λ, E_{max}, work function ϕ, speed of light c and Planck constant h to represent conservation of energy for the photoelectric effect.

[1]

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(ii) Determine the threshold frequency f_0 of the metal.

threshold frequency f_0 = _____ Hz [3]

(iii) On **Fig. 6**, sketch a second graph to represent the results for an experiment using a metal plate of higher work function. Label this graph **W**. [1]

(c) If the intensity of the light is increased while keeping the frequency constant, state and explain the effect, if any, on the

(i) number of electrons emitted per unit time; and

[1]

(ii) the maximum kinetic energy of these emitted electrons.

[3]

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Section B

Answer **one** question from this Section.

7 **(a)** State what is meant by *angular velocity*.

[1]

(b) Fig. 7 shows two satellites A and B orbiting clockwise around Earth at radii of 1.0×10^4 km and 2.0×10^4 km respectively. The mass of Earth is 6.0×10^{24} kg and the radius of Earth is 6.4×10^3 km.

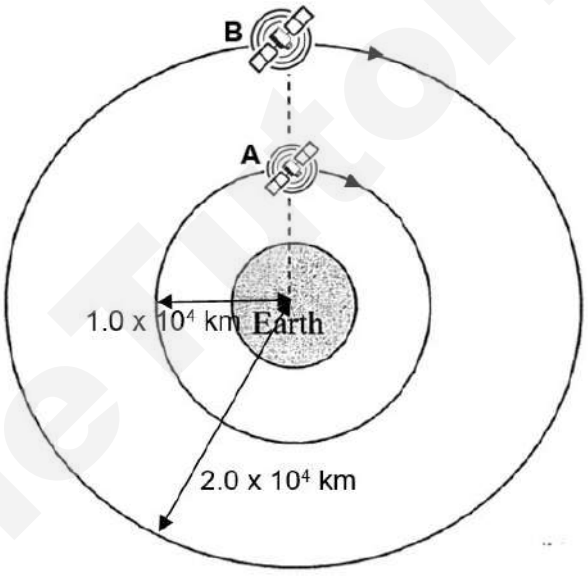

Fig. 7

(i) Determine the angular velocities of satellites A and B.

angular velocity of satellite A = _____ rad s^{-1}

angular velocity of satellite B = _____ rad s^{-1} [4]

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(ii) At t = 0 s, Satellite B is seen to be directly above Satellite A. Determine the time taken before they are diametrically opposite to each other.

time taken = _____ s [3]

(c) Define *gravitational potential* at a point in a gravitational field.

_____

_____

_____ [1]

(d) Satellite B in part (b) gradually moves to the same orbit as for Satellite A. Given that the mass of Satellite B is 100 kg, calculate for this satellite, the change in

(i) gravitational potential,

change in gravitational potential = _____ J kg^{-1} [2]

(ii) gravitational potential energy,

change in gravitational potential energy = _____ J [1]

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(iii) kinetic energy,

change in kinetic energy = _____ J [2]

(iv) total energy,

change in total energy = _____ J [1]

(e) It is common for satellites in real life to gradually lose energy due to small resistive forces. With reference to your answers in (d), suggest why many such satellites eventually 'burn up' in the Earth's atmosphere.

_____

_____

_____

_____

_____

[3]

(f) An object is projected from Earth's surface. Determine the object's minimum projected velocity for it to escape from Earth's gravitational field.

minimum projected velocity = _____ $m\ s^{-1}$ [2]

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8 **(a)** A vertical peg is fixed to the rim of a horizontal metal disc of radius *r*, rotating with a constant angular velocity ω as shown in Fig. 8.1.

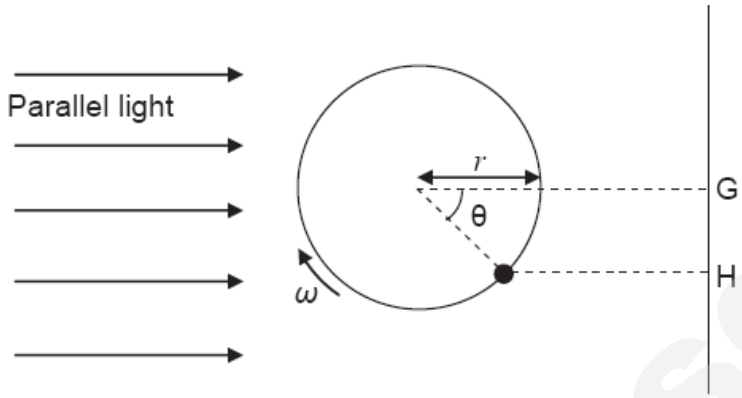

Fig. 8.1

Parallel light is incident on the disc so that the shadow of the peg is observed on a screen which is normal to the incident light. At time $t = 0$, $\theta = 0$ and the shadow of the peg is seen at G.

At some later time *t*, the shadow is seen at H.

(i) Write an expression for θ in terms of ω and *t*.

[1]

(ii) Derive an expression for the distance GH in terms of *r*, ω and *t*.

[1]

(iii) By referring to your answer to **(a)(ii),** explain why the motion executed by the shadow on the screen is simple harmonic in nature.

[3]

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(iv) The disc has a radius *r* of 10 cm and an angular speed ω of 3.5 rad s^{-1}.

Calculate, for the motion of the shadow on the screen at H when $\theta = \frac{\pi}{6}$ rad,

1. the speed of the shadow,

speed = ... m s^{-1} [2]

2. the magnitude of acceleration of the shadow.

acceleration = ... m s^{-2} [2]

(v) On Fig 8.2, sketch a graph to show how the acceleration of the shadow varies with angle θ during one revolution of the disc.

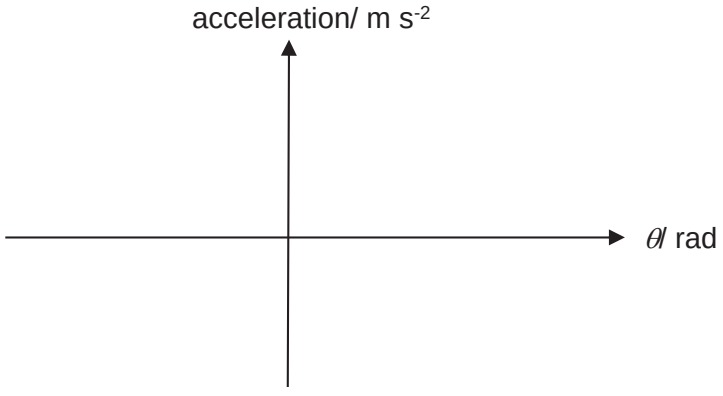

Fig. 8.2

[2]

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(b) The vertical peg is removed and the metal disc is rotating clockwise with a constant angular speed ω about its centre C in a magnetic field of flux density *B* directed into the paper. The disc makes contact at a point on its rim at R with a conductor Y while its centre C makes contact with another conductor X, as shown in Fig. 8.3.

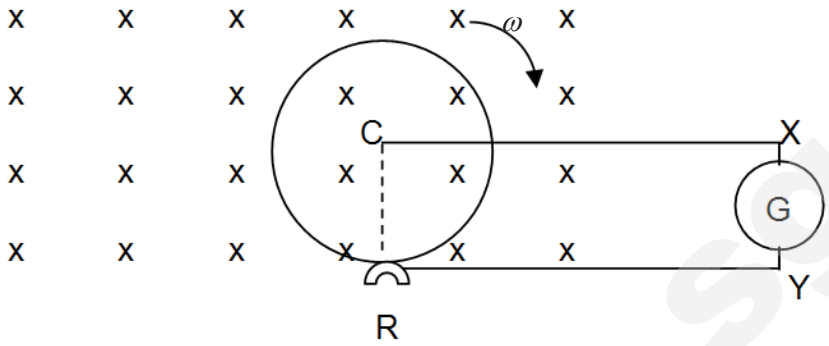

Fig. 8.3

Between C and R, there would be an induced e.m.f., which may be indicated by a galvanometer connected between X and Y

(i) Explain why an e.m.f. is generated.

[2]

(ii) Show that e.m.f. induced can be expressed as $\frac{1}{2} B\omega r^2$.

[2]

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(iii) This disc of radius *r* of 10 cm is rotating at 15 revolutions per second with its plane perpendicular to a uniform magnetic field of magnetic flux density 0.25 T.

Calculate the value of e.m.f. induced between C and R.

e.m.f = ... V [2]

(iv) State and explain the direction of induced current between C and R.

.....

.....

.....

.....

.....

.....

[3]

End of Paper

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JURONG JUNIOR COLLEGE
JC2 Preliminary Examination 2017

Name:		Class:	
		Index number:	

PHYSICS
Higher 2

9749/04

Paper 4 Practical

15 Aug 2017
2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST
Do not open this booklet until you are told to do so.

Write your name, index number and class in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
Q1	/15
Q2	/08
Q3	/20
Q4	/12
Total:	/55

(This document consists of 16 printed pages)

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1. This investigation considers the depth of hole in the container for water to flow at a suitable rate.

(a) You have been provided with a beaker labelled P containing 200g of water as shown in Fig. 1.1.

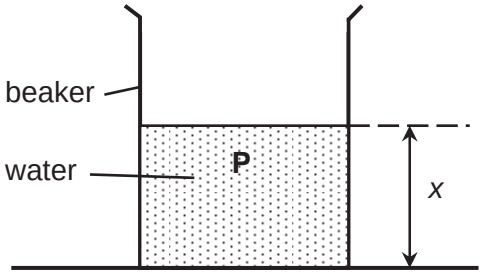

Fig. 1.1

(i) Measure and record the depth x of water in beaker P.

x = ... [1]

(ii) Estimate the percentage uncertainty in your value of x.

percentage uncertainty = ... [1]

(b) You have been provided with a plastic cup with a hole with 2 markings as shown in Fig. 1.2

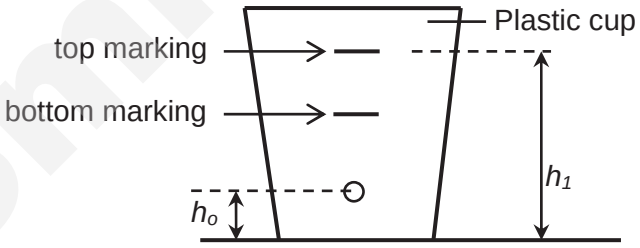

Fig. 1.2

(i) Measure and record the height of hole h_o.

h_o = ...

(ii) Measure and record the height of the top marking h_1.

h_1 = ...

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(iii) Determine the difference in height between the hole and the top marking H_1.

H_1 = ... [1]

(c) Fill the cup with water to the top marking level and cover the hole with your finger.

Place the cup on the edge of the table near the basin.

Place the beaker labelled Q in the basin, at a position where it would collect all the water that flows out of the cup when you remove your finger.

Remove your finger, start the stopwatch and allow the water to flow through the hole into the beaker Q.

When the flow of water touches the edge of the paper cup as shown in Fig. 1.3, stop the stopwatch and remove the beaker Q immediately.

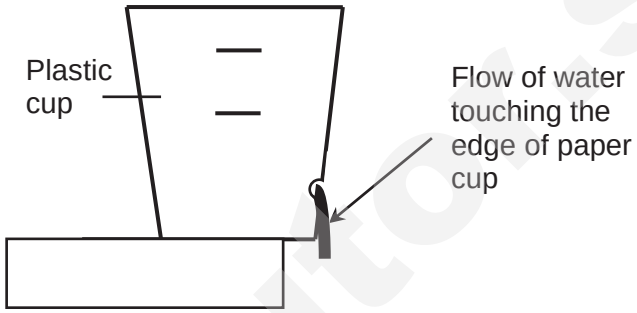

Fig. 1.3

(i) Record the time taken t_1.

t_1 = ... [1]

(ii) Measure and record the depth x_1 of water in beaker Q.

x_1 = ... [1]

(iii) Using data from **(a)(i)** and **(c)(ii)** to estimate the mass m_1 of water collected in beaker Q.

m_1 = ... [1]

(iv) Calculate the rate of flow of water, R_1 during this time.

R_1 = ... [1]

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(d) It is suggested that the rate of flow of water R is proportional to the square root of the depth of water H in the cup (i.e. the difference in height between the hole and the marking).

Use the bottom marking level on the same cup to take further measurements to investigate this suggestion.

State and explain whether or not you agree with this suggestion.
Present your measurements and calculated results clearly.

[6]

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(e) A statement found on the internet says that:

"The exit velocity of the liquid (water) decreases as the size of the hole decreases."

Suggest changes that could be made to the current investigation to study how the size of hole affects the exit velocity.

[2]

[Total: 15 marks]

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2 In this experiment, you will determine the length of a metal in the form of a wire.

(a) Measure and record the diameter *d* of the short sample A that is attached to the card.

d = ... [1]

(b) Setup the circuit as shown in Fig. 2.1.

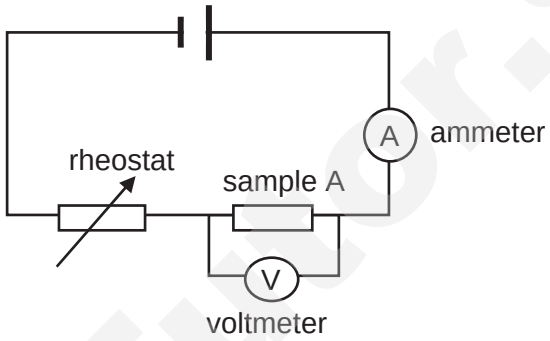

Fig. 2.1

(i) Set the rheostat to its maximum resistance.
Close the circuit
Measure the current I and the potential difference *V* across sample A.

I = ...
V = ... [1]

(ii) Open the circuit

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(iii) Vary the resistance of the rheostat and repeat **(b)(i)**, **(b)(ii)** until you have 3 more sets of I and V.

[2]

(c) Plot your values from **(b)(iii)** on Fig. 2.2.

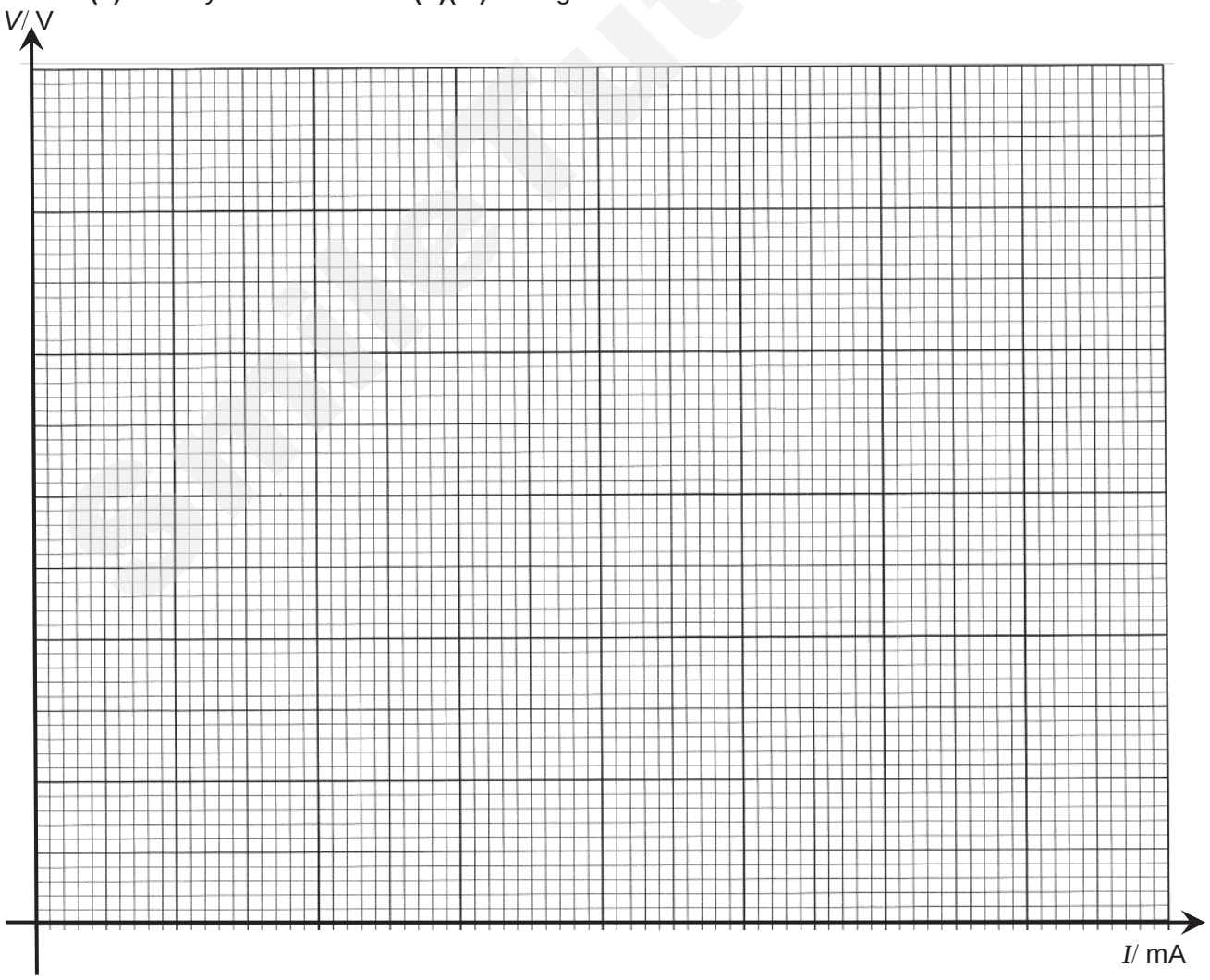

Fig. 2.2

[2]

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(d) The gradient of the graph represent the resistance of the sample A. Given that the resistance is given by

$$R=\frac{\rho L}{A}$$

where ρ is the resistivity of the metal from which the wire is made, L is the length of the wire and A is its cross-sectional area.

The resistivity of the given wire is 1.04×10^{-6} Ω m.

Estimate the length of the sample.

L = ... [2]

[Total: 8 marks]

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3 In this experiment you will set up an oscillating system which consists of a horizontal metre rule suspended by two cords from a fixed horizontal metre rule

(a) **(i)** Using the strings supplied, suspend a metre rule from the top fixed horizontal metre rule as shown in Fig. 3.1.

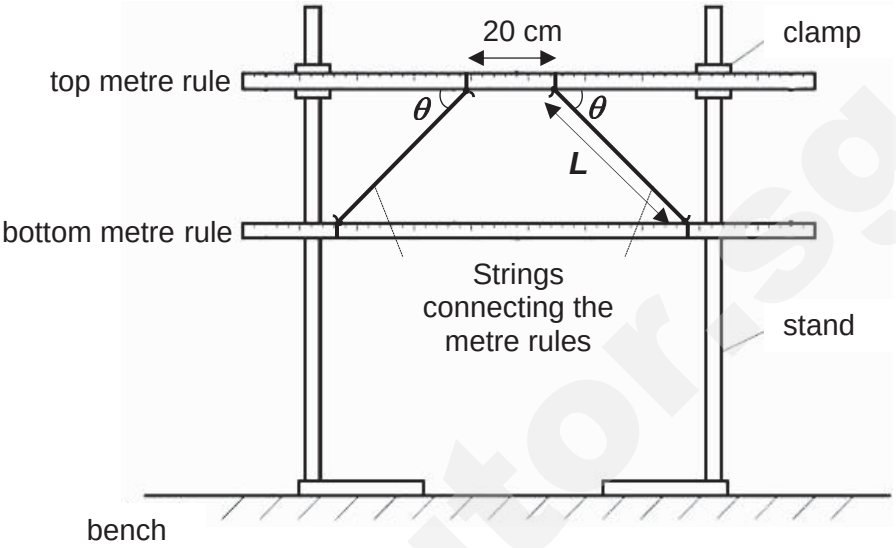

Fig. 3.1

(ii) Secure one string to the top metre rule at the 40 cm mark and another string at the 60 cm mark.

(iii) Firmly tie the ends of the strings to the bottom metre rule such that L, the length of string between the two metre rules, is about 50 cm.

(b) **(i)** Measure L, the length of the string between the two metre rules.

L = ...

(ii) Move the strings on the bottom rule to the 10 cm and 90 cm mark. Measure the angle θ.

θ = ... [1]

(iii) Estimate the percentage uncertainty in your value of θ.

percentage uncertainty = ... [1]

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(c) **(i)** Gently displace the bottom metre rule through a small angle about its centre and let it oscillate about a vertical axis through its centre as shown in Fig. 3.2.

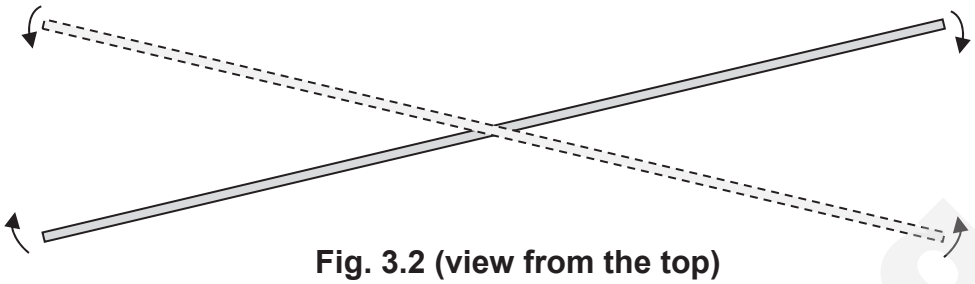

Fig. 3.2 (view from the top)

(ii) Make and record measurements to determine the period T of these oscillations.

$T =$ ..... [1]

(d) By moving the strings at the bottom metre rule, vary the angle θ to obtain further values for θ and T.

The value of L should remain constant throughout.

[6]

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(e) It is suggested that the relationship between T and θ is

$$T^2 = A(\cos\theta) + B$$

where A and B are constants.

Plot a suitable graph to determine the values of A and B.

A = ...

B = _____ [4]

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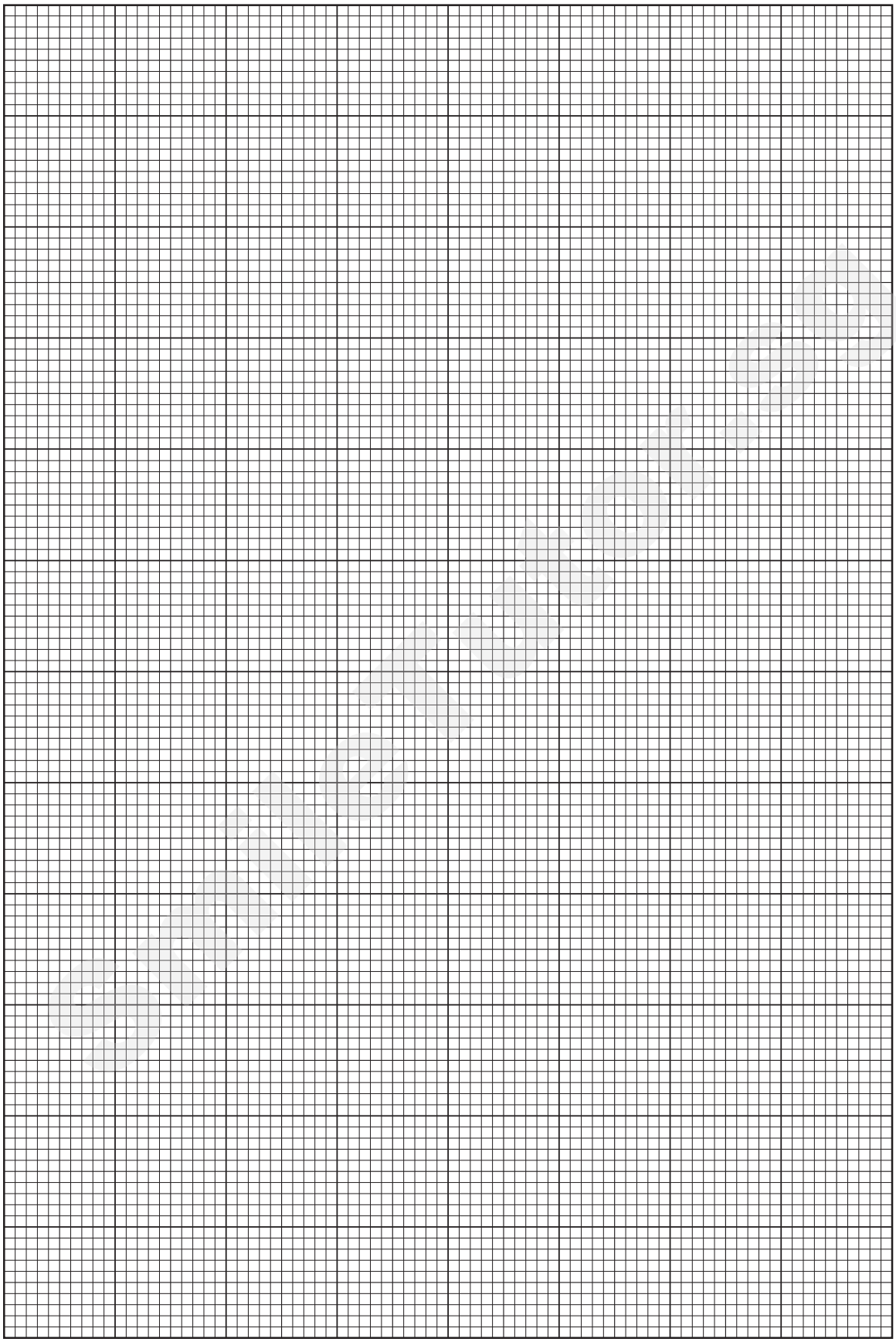

[3]

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(f) Comment on any anomalous data or results that you may have obtained. Explain your answer.

[1]

(g) State two significant source of errors in this experiment

1.

2.

[2]

(h) Suggest an improvement that could be made to the experiment to address one of the sources of errors/ limitations in **(g)**. You may suggest the use of other apparatus or a different procedure.

[1]

[Total: 20 marks]

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4 A light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as photoconductor. The LDR has a resistance of 100 Ω when it is in bright light and a resistance of 1000 Ω when no light falls on it.

Some of the practical applications of the LDR are the burglar alarm system and the automatic switch for the street lamp.

Design a laboratory experiment to investigate how the resistance *R* of the LDR varies with the distance *d* from an intense light source.

The apparatus available includes the following:

Light dependent resistor, 12 V battery, 200 Ω resistor, voltmeter, ammeter, lamp and intensity meter

You should draw diagram(s) to show the arrangement of your apparatus. In your account, you should pay attention to

(a) the apparatus you would use for the investigation,

(b) the procedure to be followed,

(c) the control of variables,

(d) any safety precautions,

(e) any precautions that you would take to improve the accuracy of the experiment.

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Diagram

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[12]

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PHYSICS DEPARMENT
JC2 Preliminary Examination 2017
9749 H2 Physics Paper 1 solutions

Qn	Ans	Suggested solution (Font Arial, 11 pt)
1	D	**A** shows **P + Q**, **B** shows **– P – Q**, **C** shows **Q – P**.
2	B	Let the time taken for the oil tanker to stop be t. $800 + 0.5t - 0.5(10)t = 20 \Rightarrow t = 173.333$ s Deceleration = $\frac{10}{173.333} = 0.058$ m s^{-2}
3	B	At t = 4 s, F = 20 N. Impulse Δp = area under the graph from t = 4 s to t = 6 s = $\frac{1}{2}(2)(20) = 20$ N s [$\Delta p = m\Delta v$] $20 = 20(\Delta v) \Rightarrow \Delta v = 1.0$ m s^{-1} Final velocity $v_f = v_i + \Delta v = 4.5 + 1.0 = 5.5$ m s^{-1}
4	B	In one second, mass of bullets hitting the wall = mn momentum of bullets hitting the wall = mnu change in momentum of bullets = $2mnu$ = momentum imparted to wall = force on wall
5	B	Both objects have the same mass and experience the same acceleration. Object A: $10 - 4 - T = ma \Rightarrow 6 - T = ma$ Object B: $T - 2 = ma$ Solving simultaneously, T = 4 N
6	B	Horizontal component of tension in string balances static friction: $T\cos 30° = 1.8$ Vertical component of tension in string balances weight of block B: $T\sin 30° = W_B$ $\tan 30° = \frac{W_B}{1.8} \Rightarrow W_B = (1.8)(\tan 30°) = 1.04$ N
7	D	Since the sphere reaches a constant velocity, the kinetic energy must be constant. Hence the change in kinetic energy is zero. The gravitational potential energy is given by $E_P = mgh$ where h is the vertical height. Since the sphere is falling at velocity v, $h = h_0 - vt$ where h_0 is the initial height and is a constant. $E_P = mg(h_0 - vt) \quad \Rightarrow \quad \frac{dE_P}{dt} = -mgv$ Hence the gravitational potential energy decreases (as indicated by the negative sign) at a rate of mgv.
8	B	**A** is wrong. The magnitude of the velocity is constant since it Is assumed that the pail is moving in uniform circular motion. **B** is correct. When we consider the most critical point at the top, the reaction force and the weight contributes to the centripetal force. As such, the centripetal force has to be greater than the weight. **C** is wrong because the centripetal force acting on the pail of water at the top is due to the tension and its weight **D** is wrong as the weight is not equal to the normal contact force at the lowest point of the circle.

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9749 H2 Physics Paper 1 solutions

Qn	Ans	Suggested solution (Font Arial, 11 pt)
9	A	Let the radius of the distant planet be R_1 and the radius of earth be R. Since the diameter of the distant planet is twice that of earth, $R_1 = 2R$ $\frac{GM}{R^2} = \frac{GM_1}{R_1^2}$ $\frac{M}{R^2} = \frac{M_1}{(2R)^2}$ $M = \frac{1}{4}M_1$ $\rho(\frac{4}{3}\pi R^3) = \frac{1}{4}\rho_1(\frac{4}{3}\pi(2R)^3)$ $\frac{1}{2} = \frac{\rho_1}{\rho}$
10	B	$\Delta U = Q + W = (-1500) + (2.0\times10^4)(0.050 - 0.025) = (-1500) + (500) = -1000$ J
11	C	Potential energy vs time, for a situation of oscillating object at extreme position at t = 0 s.
12	A	Period is not affected by amplitude. (period of spring-mass system depends on mass of object m, and spring constant k; $k = m(\frac{2\pi}{T})^2$ Total energy, E_T = max E_p = ½ k x_o^2 (where x_o = amplitude) therefore total energy is proportional to (amplitude)^2 i.e. $E_T \propto x_o^2$ $\frac{E}{E_{new}} = \frac{X^2}{(X/2)^2}$ $E_{new} = \frac{E}{4}$
13	C	A: Both particles have the highest KE at the equilibrium position. B: The particles moves up and down, not left or right. D: All the particles have the same total energy at all times.
14	C	Between 1st to 4th nodes is 1.5 wavelengths = 15 cm. Thus the wavelength is 10 cm.
15	D	Using $\sin\theta = \frac{\lambda}{b}$ $= \frac{650\times10^{-9}}{(1.0\times10^{-3})\times10^{-3}} = 0.65$ θ = **40.5º** Let distance between straight-through position and first minimum (on screen) be x, $\tan 40.5^\circ = \frac{x}{30\times10^{-2}}$ Hence, width of central maximum = 2x = (2)(tan40.5º)(20×10^{-2}) = **0.51 m**

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Qn	Ans	Suggested solution (Font Arial, 11 pt)
16	**A**	$n\lambda p < \sin 90$ $n(700\times10^{-9})400000 < 1$ $n < 3.57$ Maximum order = 3
17	**B**	$E = -\frac{dV}{dr} = 0$ where V = constant If the electric field strength is zero at a point, it only means that the potential gradient is zero at that point. But the value of the potential at that point need not be zero.
18	**A**	Resolving the initial velocity into its vertical component, $u_y = v\cos\theta$ By conservation of energy, for the electron to just reach plate AB (that is, $v_y = 0$), work done against electric force = loss in kinetic energy of electron $eV = \frac{1}{2}m_e(v\cos\theta)^2$
19	**A**	The current passing through Q and R is half of the current passing through P. Using $P = I^2R$, the power of Q and R should ¼ of P, thus the power of Q and R should be 2 W.
20	**A**	$I = \frac{Q}{t} = \frac{\rho ws}{t} = \rho wv$
21	**B**	When the slider is at position X, the voltmeter will measure the e.m.f = 4.0 V. When the slider is at position Y, the voltmeter will measure the p.d. of Q = 2.0 V.
22	**C**	$\tau = Fd$ $= 2F_B\frac{L}{2}$ $= NBIL\times L$ $= 20\times0.01\times5\times10^{-3}\times(8\times10^{-3})^2$ $= 6.4\times10^{-8}$ N m
23	**A**	$Bqv = m\,\omega\,v$ $Bq = m\,\omega$ $Bq = m\,(2\pi/T)$ Hence T = constant (since B , m and q are unchanged in this question). What changes when particle is projected with larger v, is that the radius increases, with the period remaining the same as before.
24	**C**	$E = -\frac{d\Phi}{dt} = -\frac{d(BA)}{dt} = -\frac{d(\mu_o nI)A}{dt}$ The gradient of I-t graph is E
25	**D**	The magnitude of the magnetic flux density is decreasing at a constant rate implies that the e.m.f induced is constant. By Lenz's law, the induced current will flow so as to oppose the decreasing magnetic field, and using Right Hand Grip Rule, current will flow counter-clockwise.

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9749 H2 Physics Paper 1 solutions

Qn	Ans	Suggested solution (Font Arial, 11 pt)
26	**A**	$P_{mean} = \frac{1}{4}P_o = \frac{1}{4}(\frac{3^2}{5}) = 0.45$ W
27	**D**	$p = mv = \frac{h}{\lambda} \Rightarrow v = \frac{h}{mv}$ Hence, the most massive particle would have the smallest velocity.
28	**B**	Assuming range of wavelength for visible light to be 400 – 700 nm, the range of photon energies that would lead to visible spectral lines is about 1.8 – 3.1 eV. Since the gas is cold, the atom is at the ground state i.e. –13.6 eV level. Electrons of KE 13.00 eV would be able to excite it up to only the –0.850 eV level. From the –0.850 eV level, only the following transitions would lead to emission of photons with energies in the range of 1.8 – 3.1 eV. • from –0.850 eV to –3.40 eV level • from –1.51 eV to –3.40 eV level
29	**B**	$A = A_0 \exp(-\lambda t)$ $\ln A = \ln A_0 - \lambda t$ Hence, gradient of graph of ln A against t is - λ (which is a constant for the same radioactive gas since $\lambda = \ln 2/t_{1/2}$).
30	**C**	$\frac{A}{A_0} = (\frac{1}{2})^n$ $\Rightarrow \frac{(35-20)}{(80-20)} = (\frac{1}{2})^n$ => n = 2 half-lives = 2 x 5700 years ≈ 11 000 years

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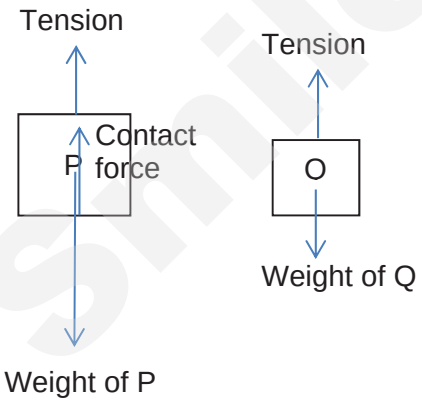
PHYSICS DEPARTMENT
2017 H2 P2 Prelim Solution

Qn	Suggested solutions	Remarks
1(a)	Using $s = ut + \frac{1}{2}at^2 \rightarrow h = \frac{1}{2}at^2$ $a = \frac{2h}{t^2} = \frac{2(0.600)}{\left(354 \times 10^{-3}\right)^2}$ $a = 9.5758 \text{ m s}^{-2}$ $\frac{\Delta a}{a} = \frac{\Delta h}{h} + \frac{2\Delta t}{t}$ $\frac{\Delta a}{9.5758} = \frac{0.001}{0.600} + \frac{2(1)}{354}$ $\Delta a = 0.07 \text{ m s}^{-2}$ $a = (9.58 \pm 0.07) \text{ m s}^{-2}$	**[1] ans: acceleration** **[1] ans: uncertainty** **[1] e.c.f. final expression (correct s.f. for uncertainty, correct d.p. for acceleration of free fall)**
(b)(i)	The delay is due to the time taken for the electromagnet and steel ball to lose their magnetism.	**[1]**
(ii)	Systematic error. The constant delay causes the timing measured to be consistently too long.	**[1]** **[1]**
(iii)	Graphical methiod: Measure the timings for different heights of fall and plot a graph of h against t^2. Details: The constant delay is the square root of the x-intercept. OR Experimental method: Use of light gates / high speed camera / etc. Details: Positioning of light gates / view video in slow motion / etc.	**[1] accept graphical or experimental method** **[1] some details**
2(a)(i)		**[2] for 3 forces on P, [1] for 2 forces on Q. Minus 1 mark if no label and/or wrong point(s) of application and/or wrong relative magnitudes showing non-equilibrium.**
(ii)	Object Q: tension balances the weight of object Q Object P: tension + contact force balances the weight of object P (0.3)(9.81) + contact force = (1.5)(9.81) Contact force = (1.2)(9.81) = 11.8 = 12 N (shown)	**[1] equate tension to weight of object Q** **[1] sub**
(b)(i)	Upthrust is the upward force exerted on an object immersed in a fluid. It is equal to the weight of fluid displaced.	**[1]**
(ii)	12 = (A)(0.120)(1000)(9.81) A = 0.010 m^2	**[1] sub** **[1] ans**
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Qn	Suggested solutions	Remarks
3(a)	Power is defined as the rate of work done/ work done per unit time/ rate of energy conversion.	**[1]**
(b)	For car to move at constant velocity, the minimum engine force required must be equal in magnitude to component of car's weight along slope. Hence, $F = mg\sin\theta$ $= (1800)(9.81)\sin(37.5°)$ $=1.07 \times 10^4$ N Minimum power $P = Fv = (1.07 \times 10^4)(60 \times 10^3/3600)$ $= 179$ kW	**[1]-sub** **[1]-sub** **[1]-ans**
(c)	Gain in KE = Loss in GPE $\frac{1}{2} mv^2 = mgh$ $\frac{1}{2} v^2 = (9.81)(77.2 \sin 37.5°)$ $v = 30.4$ m s^{-1}	**[1]-sub** **[1]-ans**
4(a)	Period is the time taken for a wave particle to complete one oscillation.	**[1]**
(b)	2 cm	**[1]**
(c)	Q directly below P	**[1]**
(d)	Phase difference $= (0.25/2) \times 2\pi$ $= \pi/4$ rad	**Subst- [1]** **Ans- [1]**
(e)	$\frac{0.1}{T} = \frac{\frac{\pi}{4}}{2\pi}$ $T = 0.80$ s	**Subst- [1]** **Ans- [1]**
5(a)(i)	$a = -\omega^2 x$ $\omega = \sqrt{gradient}$ $= \sqrt{\frac{7.6-0}{0.10-0}}$ $= 8.7$ rad s^{-1}	**[1] relating gradient to ω^2** **[1] working**
(a)(ii)	$T = 2\pi / \omega$ $= 2\pi / 8.7$ $= 0.72$ s	**[1] ans**
(b)(i)	$x = -x_o \cos \omega t$ (Since starting point is at lowest point of motion)	**[1]**
(b)(ii)	$-0.025 = -0.10 \cos(8.7t)$ $t = 0.15$ s	*Ecf from (b)(i)* **[1] working** **[1] ans**
(c)	**Resonance** occurs. The **frequency of passing over the bumps matches the natural frequency** of the suspension of the truck.	**[1]** **[1]**
6(a)(i)	Magnetic force is acting **downward**. Since **side BC is perpendicular to the magnetic field** *B* of the solenoid, it would **experience a magnetic force whose direction is given by Fleming's Left Hand Rule**.	**[1]** **[1]**

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Qn	Suggested solutions	Remarks
(a)(ii)	Since side AB is **parallel with the magnetic field** *B* of the solenoid, **no magnetic force** acts on it.	**[1]**
(b)(i)	$B = \mu_0 nI$ $= 4\pi \times 10^{-7} \times 700 \times 3.5$ $= 3.08 \times 10^{-3}$ T	**[1] ans**
(b)(ii)	Force acting on BC $F = BIL$ $= 3.08 \times 10^{-3} \times 3.5 \times 5.0 \times 10^{-2}$ $= 5.39 \times 10^{-4}$ N	**[1] sub** **[1] ans**
(b)(iii)	Since frame is horizontal, applying Principle of Moments, Sum of anti-clockwise moments = Sum of clockwise moment $mgd = Fd_{QC}$ $(0.100 \times 10^{-3})(9.81)(d) = (5.39 \times 10^{-4})(12 \times 10^{-2})$ $d = 0.0659$ m	**[1] sub** **[1] ans**
(b)(iv)	The **clockwise moment will increase by 4 times** as magnetic field strength through solenoid and current is doubled. The mass of the paper must be **increased by 4 times** so that the anticlockwise moment will be increased by 4 times.	**[1]** **[1]**
7(a)	*Half-life* of a radioactive nuclide is defined as the <u>average time taken for half of the original number of radioactive nuclei in a sample to decay</u>. Or any of the following: - half of the original number of radioactive nuclei in a sample to remain undecayed; - the activity of a radioactive sample to decrease to half its original value; - the received count rate to reduce to half its original value. (assume no background count rate).	**[1]**
(b)(i)	The *binding energy per nucleon* is the <u>minimum energy per nucleon needed to split a nucleus into separate nucleons</u>.	**[1]**
(ii)	Nucleon number = 216 Proton number = 84	**[1] - ans**
(iii)	Energy change = [(7.76)(216) + (6.51)(4)] - (7.72)(220) = 3.80 MeV $= 3.80 \times 10^{6} \times 1.6 \times 10^{-19}$ $= 6.08 \times 10^{-13}$ J	**[1] – sub (ecf for (ii))** **[1] – ans (MeV)** **[1] – ans (J)**

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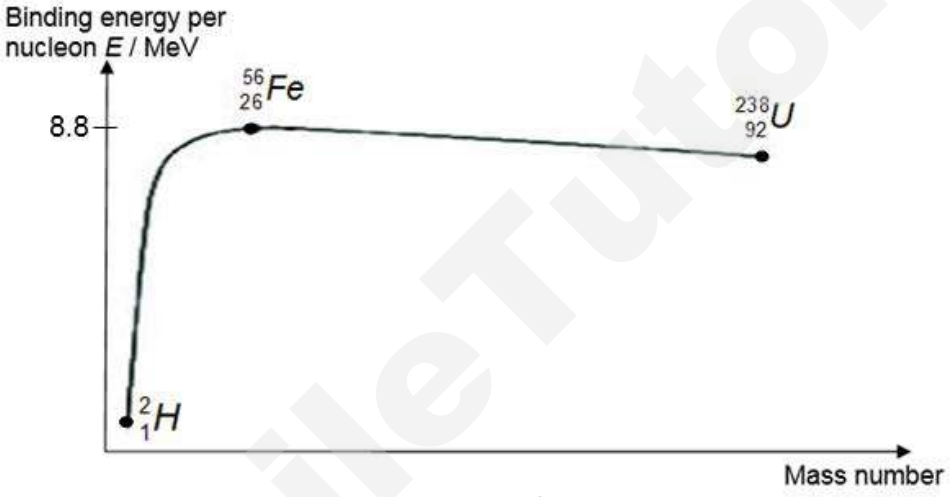
Qn	Suggested solutions	Remarks
(iv)	Energy is **released** in this reaction. The total binding energies of the reactants is lower than the total binding energy of the product. It means that the reaction involves reactants of higher energy content to products with lower energy content. OR The mass-energy of reactants is greater than mass energy of products. OR Products are more stable than reactants. *Therefore, 3.80 MeV energy which is the difference in the energy content is released in this reaction in the form of K.E. of the products. (note)*	**[1]** **[1]** **[1]**
(v)		**[1] correct axes and correct shape of graph** **[1] position of nuclides** **[1] correct maximum value of 8.8 MeV**
8(a)(i)	$T^2 \propto r^3 \Rightarrow T^2 = kr^3 \Rightarrow k = \frac{T^2}{r^3}$ $k_1 = \frac{1.63^2}{(7010)^3} = 7.71\times10^{-12}$ $k_2 = \frac{48.1^2}{(67100)^3} = 7.65\times10^{-12}$ $k_2 = \frac{57.2^2}{(75200)^3} = 7.69\times10^{-12}$ Since k_1,k_2 and $k_3$are about the same, the relationship is true.	**[1] for method** **[1] for comparing at least 2 correct values**
(ii)	$k_{ave} = 7.68\times10^{-12}$ Since $T^2 = (7.68\times10^{-12})r^3$ $\Rightarrow 35^2 = (7.68\times10^{-12})r^3$ $r = 54232 \approx 54200$ km	**[1] for any correct method** **[1] for answer** **Accept answer even if student does not take average**

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Qn	Suggested solutions	Remarks
(b)(i)	Useful intensity of light received = $0.16 \times 1500 = 240$ $I = \frac{P}{Area} \Rightarrow Area = \frac{P}{I} = \frac{360}{240} = 1.5\ m^2$	**[1] for correct method** **[1] for correct answer**
(ii)	The satellite will sometimes be in the shadow cast be Earth/ no direct sunlight The electrical circuits/ batteries are not 100% efficient Satellites required extra power for position control or other stated function Panels may not be perpendicular to sunlight. Radiation damage (from cosmic rays) reduces number of useful cells	**[2]** **Any two of the following.**
(iii)	The intensity of sunlight is too small. The rea of panel would be too large or massive to be launched	**[1]** **Any one of the following**
9(a)(i)	For diameter = 6.0 m and v = 3.0 m s-1, P = 150 W. lg P = 2.18	**[1]**
(ii)	1. correct point plotted. 2. suitable best-fit line	**[1]** **[1]**
(iii)	$\text{Gradient} = \frac{3.45 - 1.90}{0.91 - 0.38}$ n = 2.93 (to 3 s.f) (Accept n = 2.95 ± 0.05) Sub (0.38, 1.90) and gradient = 2.93, 1.90 = (2.93) (0.38) + y-intercept y-intercept = 0.7866 lg k = 0.7866 k = 6.12	**[1] for correct method** **[1] for correct n** **[1] for correct k**
(b)(i)	Volume of air in 1s = $\pi r^2 v = \pi(\frac{6}{2})^2(8.0) = 226.2 \approx 226\ m^3$	**[1]**
(ii)	Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}(\rho V)v^2$ $= \frac{1}{2}(1.3)(226.2)(8.0)^2 = 9409 \approx 9410$ J	**[1] for correct method** **[1] for correct answer**
(c)	efficiency = $\frac{\text{useful power output}}{\text{total power output}} = \frac{2750}{9409} = 0.292$	**[1]**
(d)	• Type of material used for the blades. A lighter material has smaller inertia in rotating and hence the power output will be higher. • Shape of the blades. An aerodynamic shape will cause the power output to be higher. • Surface area of the blade. A larger surface area implies that more wind is in contact with the blade and the power output will be higher. • Friction between the wheel and the axle. A higher friction would mean that more energy is lost through heat, causing the power output to be less	**[1] for any of the following reasons**

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Qn	Suggested solutions	Remarks
(e)	• The wheel of diameter 30 m may be too heavy to mount during construction. • The wheel produces a very large torque, hence may be unstable. • To provide a strong frame to support it, it may be costly. • There may be space constraints to construct long blades as they extend 30m high up.	**[1] for any of the following reasons**

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2017 H2 Prelim Paper 3 Solution

Qn	Suggested solutions	Remarks
1 (a)(i)	The principle of conservation of linear momentum states that the total momentum of a system of interacting bodies is constant provided no external resultant force acts on it.	**[1]**
(ii)	Total final momentum = total initial momentum $1.5v_A + 5v_B = (1.5)(4) = 6$ Relative speed of separation = relative speed of approach $v_B - v_A = 4$ Solving simultaneously, $v_A = -2.154 = -2.2$ m s^{-1} $v_B = 1.846 = 1.8$ m s^{-1}	**[1] eqn** **[1] eqn (also accept eqn of KE conservation)** **[1] v_A ans (must be –ve)** **[1] v_B ans**
(b)	Consider the vertical motion to determine time of flight: $s = ut + \frac{1}{2}at^2$ $0.6 = \frac{1}{2}(9.81)t^2$ $t = 0.350$ s Consider the horizontal motion to determine horizontal distance travelled: $s = (1.2)(0.350) = 0.420$ m	**[1] sub** **[1] ans** **[1] ans**
(c)	The GPE gained during free fall is dissipated by this vertical retarding force. $mgh = Fd$ $(5)(9.81)(0.6+0.08) = F(0.080)$ $F = 417$ N	**[1] sub** **[1] ans**
2(a)	The gas molecules are in continuous random motion. When they collide with the walls of the container, they experience change in momentum. Rate of change of momentum is force acting on the gas. Force per unit area is pressure. Using Newton's Third Law of Motion, since there is pressure exerted on the gas by the container, there must be pressure exerted by the gas on the container.	**[1]** **[1]** **[1]**
(b)(i)	$pV = nRT$ $(1.0 \times 10^5)V = (1)(8.31)(300)$ $V = 0.02493 = 0.025$ m^3	**[1] sub**
(ii)	$\text{Density} = \frac{\text{mass}}{\text{volume}} \rightarrow \rho = \frac{0.032}{0.025} = 1.28$ kg m^{-3}	**[1] ans**
(iii)	$p = \frac{1}{3}\rho c_{rms}^{\ 2} \rightarrow 1.0\times10^5 = \frac{1}{3}(1.28)c_{rms}^{\ 2}$ $c_{rms} = 484$ m s^{-1}	**[1] sub** **[1] ans**
(iv)	average KE of molecule $= \frac{3}{2}kT = \frac{3}{2}(1.38\times10^{-23})(300)$ $= 6.21\times10^{-21}$ J	**[1] sub** **[1] ans**
3(a)	Using $x = \frac{\lambda D}{a} = \frac{690\times10^{-9}\times2.5}{0.800\times10^{-3}} = 2.16\times10^{-3} m$	**[1] formula** **[1] sub** **[1] ans**
(b)(i)	There is no change in the spacing. The maxima is the brighter and thus the contrast is higher.	**[1]** **[1]**

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Qn	Suggested solutions	Remarks
(ii)	Since D is larger, x will be larger. The separation will increase. The maxima is dimmer due to the longer distance, thus the contrast is lower.	**[1]** **[2]**
(iii)	Since wavelength of green light is shorter, x will be smaller. The separation will decrease. The contrast remains unchanged.	**[1]** **[1]**
4(a)(i)	From the graph, at 2.0 V, I = 2.0 A → R = 1.00 Ω From the graph, at 10.0 V, I = 5.1 A → R = 1.96 Ω	**[1]** **[1] read off values correctly** **[1] ans**
(a)(ii)	Lattice ions in the metal to vibrate more vigorously, causing an increased rate of collision with the moving electrons. The increased rate of collision reduces the rate of flow of electrons, hence, lowering the current flow.	**[1]** **[1]**
(b)(i)	$R = \frac{\rho\ell}{A} = \frac{4\rho\ell}{\pi d^2}$ $0.50 = \frac{4(5.5\times10^{-8})\ell}{\pi(0.084\times10^{-3})^2} \Rightarrow \ell = 0.0503$ m	**[1] Value of A** **[1] Eqn** **[1] sub** **[1] ans**
(b)(ii)	The length of the filament wire is too long to be placed inside the filament lamp.	**[1]**
5(a)	Electric field strength at a point in an electric field is defined as the electric force exerted per unit positive charge placed at that point.	**[1]**
(b)(i) 1.	B is positively charged because the electric field lines point to the left away from sphere B, and electric field lines point away from positive charges.	**[1]**
(b)(i) 2.	Electric potential is constant inside each sphere, because zero electric field strength within a sphere implies zero potential gradient.	**[1]** **[1]**
(b)(ii)	$Q_A = 4Q_B$ ---------- (1) At x = 4.0 cm, $E_A - E_B = 1.25 \times 10^7$ $Q_A/[4\pi\varepsilon_0(0.04)^2] - Q_B/[4\pi\varepsilon_0(0.08)^2] = 1.25 \times 10^7$ ---------- (2) Substituting (1) into (2), $4Q_B/[4\pi\varepsilon_0(0.04)^2] - Q_B/[4\pi\varepsilon_0(0.08)^2] = 1.25 \times 10^7$ Solving, $Q_B = 5.93 \times 10^{-7}$ C	 **[1] eqn (2)** **[1] working** **[1]**

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Qn	Suggested solutions	Remarks
(b)(iii)	Gain in electric potential = area under graph between x = 1.4 cm and x = 3.0 cm Estimated area between x = 1.4 cm and x = 3.0 cm = ½ $(0.6 \times 10^{-2})(10.0 \times 10^{7})$ + ½ $(0.6 \times 10^{-2})(1.5 \times 10^{7})$ + ½ $(1.6 \times 10^{-2})(6.0 + 2.5)10^{7}$ + $(0.2 \times 10^{-2})(0.5 \times 10^{7})(3.5)$ = 1060 kV Or by counting squares under graph. Acceptable range for either method is between 800 kV and 1100 kV. Energy gained by proton = $(1060 \times 10^{3})(1.60 \times 10^{-19})$ $= 1.70 \times 10^{-13}$ J	**[1] area under graph** **[1] area within range** **[1] sub** **[1] ans**
6(a)	Work function is the <u>minimum energy required to liberate/emit an electron</u> from the surface.	**[1]**
(b)(i)	$hc/\lambda = \phi + E_{MAX}$	**[1]**
(b)(ii)	From (b)(i), $hc/\lambda = hf_0 + E_{MAX}$ when $E_{MAX} = 0$, $1/\lambda_0 = 1.95 \times 10^{6}$ m^{-1} (allow $\pm 0.05 \times 10^{6}$ m^{-1}) (<u>evidence</u> of use of y-intercept from graph) $f_0 = c(1/\lambda_0) = (3.00 \times 10^{8})(1.95 \times 10^{6})$ $= 5.85 \times 10^{14}$ Hz OR chooses point on the line and substitutes values of $1/\lambda$ and E_{MAX} into $hc/\lambda = \Phi + E_{MAX}$	**[1] method** **[1] sub** **[1] ans**
(b)(iii)	Same gradient, towards left of original graph (implying larger y-intercept)	**[1]**
(c)(i)	($I = \frac{Nhf}{tA} \Rightarrow$ when I increases, it can mean $\frac{N}{t}$ increases or f increases.) <u>Number of electrons emitted per unit time increases</u> because there are now <u>more photons striking the metal surface per unit time</u>.	**[1]**
(c)(ii)	<u>E_{MAX}</u> of emitted photoelectron is the <u>same</u> as <u>photon-electron interaction is 1 to 1</u>, and since f is fixed, <u>energy of photon</u> absorbed by electron <u>is constant</u> and for same surface with same work function.	**[1]** **[1]** **[1]**
7(a)	Angular velocity is the <u>rate of change of angular displacement</u>.	**[1]**

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Qn	Suggested solutions	Remarks
(b)(i)	Since gravitational force (on satellite due to Earth) provides the centripetal force for each satellite to orbit around Earth, $\frac{GM_E m}{r^2} = mr\omega^2$ $\omega = \sqrt{\frac{GM_E}{r^3}}$ $\omega_A = \sqrt{\frac{(6.67x10^{-11})(6.0x10^{24})}{(1.0x10^4 x10^3)^3}} = 6.33x10^{-4} rads^{-1}$ $\omega_B = \sqrt{\frac{(6.67x10^{-11})(6.0x10^{24})}{(2.0x10^4 x10^3)^3}} = 2.24x10^{-4} rads^{-1}$	**[1] - statement** **[1] - expression** **[1] – ans** **[1] - ans**
(b)(ii)	When satellites are diametrically opposite to each other, the difference in their angular displacement = 180° = π rad. Since $\omega = d\theta/dt$, => $\Delta\theta = \Delta\omega\Delta t$ => $\pi = (\omega_A - \omega_B)\,\Delta t$ $= (6.33 \times 10^{-4} - 2.24 \times 10^{-4})\Delta t$ $\Delta t = 7.68 \times 10^3$ s	**[1]- $\Delta\theta = \pi$ rad** **[1] – sub.** (accept ecf) **[1] - ans**
(c)	The gravitational potential at a point is defined as the work done per unit mass in bringing a small test mass from infinity to that point.	**[1]**
(d)(i)	Gravitational potential $\phi = -\frac{GM}{r}$ $\Delta\phi = -\frac{GM_E}{r_A} - (-\frac{GM_E}{r_B})$ $\Delta\phi = GM_E(-\frac{1}{r_A} + \frac{1}{r_B})$ $\Delta\phi = (6.67x10^{-11})(6.0x10^{24})(-\frac{1}{1.0x10^4 x10^3} + \frac{1}{2.0x10^4 x10^3})$ $= -2.00 \times 10^7$ J kg^{-1}	**[1] – sub** **[1] - ans**
(d)(ii)	ΔGPE = $m_B\Delta\phi$ = (100)(-2.00 x 10^7) = - 2.00 x 10^9 J	**[1] – ans** (accept ecf)
(d)(iii)	Change in KE = $\frac{GM_E m_B}{2r_A} - \frac{GM_E m_B}{2r_B}$ $= \frac{(6.67x10^{-11})(6.0x10^{24})(100)}{2}(\frac{1}{1.0x10^7} - \frac{1}{2.0x10^7})$ = 1.00 x 10^9 J	**[1] – subst** **[1] - ans**
(d)(iv)	Change in total energy = ΔGPE + ΔKE = - 2.00 x 10^9 + 1.00 x 10^9 = -1.00 x 10^9 J	**[1] – ans** (accept ecf)

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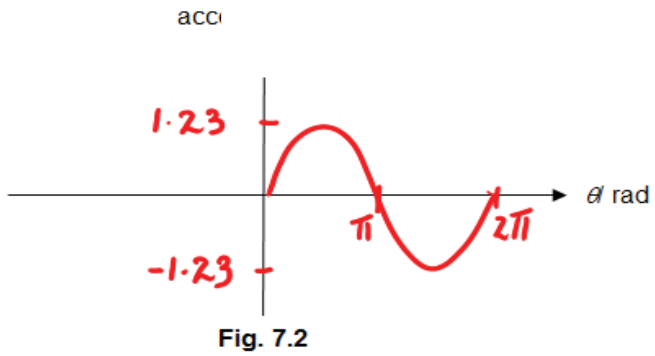
Qn	Suggested solutions	Remarks
(e)	As the satellite loses energy, its <u>orbital radius decreases</u> and its kinetic energy will increase and <u>it will move faster</u>. As the <u>work done against resistive forces by the satellite increases</u>, it will 'burn up' as its potential energy is increasingly <u>converted to thermal energy</u>.	**[1]** **[1]** **[1]**
(f)	Escape velocity = $\sqrt{\frac{2GM_E}{r_E}}$ $= \sqrt{\frac{2(6.67x10^{-11})(6.0x10^{24})}{(6.4x10^3 x10^3)}}$ $= 1.12 \times 10^4$ m s^{-1}	**[1] – sub** **[1] - ans**
8(a)(i)	$\theta = \omega t$	**[1]**
(ii)	Distance GH = r $\sin\theta = $ r $\sin\omega t$	**[1]**
(iii)	Let GH = y $y = -r\sin\omega t$ $v = -r\omega\cos\omega t$ $a = r\omega^2 \sin\omega t = -\omega^2 y$ Since it is periodic motion in which acceleration is proportional and opposite of its displacement from the equilibrium position, It is SHM.	**[2] for manipulation (Accept $y = r\sin\omega t$)** **[1] for explaining/ defining SHM**
(iv)1.	$v = -r\omega\cos(\omega t) = -(0.10)(3.5)\cos(30^o) = -0.303$ ms^{-1} speed = 0.303 ms^{-1}	**[1] for substitution** **[1] for correct answer** **Accept other method.**
2.	$a = r\omega^2 \sin\omega t = (0.10)(3.5^2)\sin(30^0) = 0.613$ ms^{-2}	**[1] for substitution** **[1] for correct answer** **Accept other method.**
(v)	 **Fig. 7.2**	**[1] for correct shape** **Accept - sinθ.** **[1] for correct labelling**

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2017 H2 Prelim Paper 3 Solution

Qn	Suggested solutions	Remarks
(b)(i)	The narrow strip of the metal disc between C and R acts as a straight conductor. When the disc rotates, this strip will be cutting magnetic flux with time. By Faraday's law, there will be an e.m.f induced.	**[1]** **[1]**
(ii)	$\varepsilon = \frac{d\phi}{dt} = \frac{d(BA)}{dT}$ $= B\left(\frac{dA}{dt}\right) = \frac{B(\pi r^2)}{T} = \frac{B(\pi r^2)}{\frac{2\pi}{\omega}} = \frac{1}{2}B\omega r^2$	**[1]** **[1]**
(iii)	$\omega = \frac{15(2\pi)}{1} = 30\pi$ $\text{e.m.f} = \frac{1}{2}B\omega r^2 = \frac{1}{2}(0.25)(30\pi)(0.10)^2 = 0.118$ V	**[1] for calculating ω** **[1] for correct answer**
(iv)	Current flow from C to R. According to Lenz's law, the direction of the induced current along CR would be such as to produce a force acting to the right, to oppose the change. In order that the force acting on CR would be to the right, the induced current must be flowing from C to R (centre to rim) along CR by Fleming's left hand rule.	**[1]** **[1]** **[1]**

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Suggested marking scheme for 2017 Prelim Examination Paper 4

Qn	Answer	Marks
1(a)(i)	**MMO** x measured to the correct precision with unit	1
(ii)	**ACE** Sensible value in Δx (allow 2 to 5mm) and hence corresponding percentage uncertainty of x (to a maximum of 2 s.f.)	1
(b)(i)(ii)(iii)	**MMO** h_o, h_1 *and* H_1 are measured to the correct precision with unit	1
(c)(i)	**MMO** t are measured to the correct precision with unit and there is evidence of repeated reading.	1
(ii)	**MMO** x_1 are measured to the correct precision with unit and there is evidence of repeated reading.	1
(iii)	**ACE** Estimation of m_1 using ratio of x *and* x_1 values and 200 g with correct unit.	1
(iv)	**ACE** Flow rate R_1 with appropriate number of significant figures with units	1
(d)	**MMO** Measurement of h_2, H_2, t_2, x_2 and m_2 for lower marking, **ACE** Calculation of R_2. **PDO** Values of h_2, H_2, t_2, x_2 and m_2 to appropriate precision **PDO** Flow rate R_2 with appropriate number of significant figures with units, e.g. g s^{-1} **ACE** Determination of a constant of proportionality. **ACE** Draw conclusion based on stated criterion e.g. not obeyed because more than 20% difference in values of k.	6
(e)	**P** Use holes of different size with the same depth **P** Calculation of exit velocity by dividing the mass flow rate with density and area of hole	2
2(a)	**MMO** d are measured to the correct precision with unit and there is evidence of repeated reading.	1
(b)(i)	**MMO** I *and* V are measured to the correct precision with unit	1
(iii)	**MMO** Take three readings showing correct trend. Allow tables with three readings. **MMO** I *and* V are measured to the correct precision with unit	2
(c)	**PDO** Points are correctly plotted. **PDO** Line of best fit.	2

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(d)	**ACE** Calculation of gradient **ACE** Determination of length L with appropriate number of significant figures with units,	**2**
3(b)(i)(ii)	**MMO** Value of L to the nearest mm with unit Value of θ to the nearest degree with unit	**1**
(iii)	**ACE** Percentage uncertainty in θ correctly calculated. $\Delta\theta \geq 2°$.	**1**
(c)(ii)	**MMO** Repeated timings for each value of θ with the number of oscillations n taken such that $nT \geq 10$ s.	**1**
(d)	**MMO** • Award 2 marks if candidate has successfully collected 6 or more sets of data (x, T) without assistance / intervention and there is evidence of repeat readings • Award 1 mark if candidate has successfully collected 5 sets of data (x, T) without assistance/intervention. • Award zero mark if candidate has successfully collected 4 or fewer sets of data (x, T) without assistance/intervention. • Deduct 1 mark if candidate requires some assistance /intervention but has been able to do most of the work independently. • Deduct 2 marks if candidate has been unable to collect data without assistance/ intervention.	**2**
	PDO Layout: column headings (raw data and calculated quantities: θ, t, T, $T^2$and $\cos\theta$). Each column heading must contain a quantity and unit.	**1**
	PDO All values of e.g. θ, t to the correct precision.	**1**
	PDO For each calculated value of e.g. T, $T^2$and $\cos\theta$, the number of s.f. should be the same or one more than the number of s.f, in the raw data.	**1**
	ACE Correctly calculated values of calculated quantity.	**1**
(e)	**ACE** Linearising equation.	**1**
	ACE y-intercept must be read off to the nearest half small square or determined from y = mx + c using a point on the line.	**1**
	ACE Gradient - the hypotenuse of the gradient triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square	**1**
	ACE Values of A and B calculated correctly with units.	**1**
	PDO	**1**

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	• Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. • Scales must be chosen so that plotted points occupy at least half the graph grid in both x and y directions. • Axes must be labelled with the quantity and units which is being plotted.	
	PDO All observations must be plotted. Work to an accuracy of half a small square.	**1**
	PDO Straight line of best fit - judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.	**1**
(f)	**MMO** Anomalous data/results, if any, must be identified" Appropriate justification must be given" Otherwise comment on absence of anomalous data. (only 2 anomalous data allowed)	**1**
(g)	**ACE** Relevant points (with appropriate elaboration) might include:	**2**
(h)	**ACE** Relevant points (with appropriate elaboration) might include:	**1**

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Suggested solutions

1(a)(i)	x = 65 mm
(ii)	Percentage uncertainty= $\frac{3}{65}\times 100\% = 4.6\%$ (Allow a maximum of 2 s.f.)
(b)(i)	h_o= 17 mm
(ii)	h_1= 60 mm
(iii)	H_1 = 43 mm
(c)(i)	$t_1 = \frac{t_a + t_b}{2} = \frac{29.4 + 29.8}{2} = 29.6$ s
(ii)	$x_1 = \frac{x_a + x_b}{2} = \frac{27 + 29}{2} = 28$ mm
(iii)	$\frac{x}{x_1} = \frac{m}{m_1} \Rightarrow \frac{65}{28} = \frac{200}{m_1} \Rightarrow m_1 \approx 86$ g
(iv)	$R_1 = \frac{86}{29.6} \approx 2.9$ g s^{-1}
(d)	h_2 = 40 mm H_2 = 23 mm $t_2 = \frac{t_a + t_b}{2} = \frac{13.2 + 13.6}{2} = 13.4$ s $x_2 = \frac{x_a + x_b}{2} = \frac{12 + 12}{2} = 12$ mm $\frac{x}{x_2} = \frac{m}{m_2} \Rightarrow \frac{65}{12} = \frac{200}{m_2} \Rightarrow m_2 \approx 37$ g $R_2 = \frac{37}{13.4} \approx 2.8$ g s^{-1} $R \propto \sqrt{H} \Rightarrow R = k\sqrt{H}$ when H_1 = 43 mm, R_1 = 2.9 g s^{-1}, $k_1 = \frac{R_1}{\sqrt{H_1}} = \frac{2.9}{\sqrt{43}} = 0.44$ when H_1 = 23 mm, R_1 = 2.8 g s^{-1}, $k_1 = \frac{R_1}{\sqrt{H_1}} = \frac{2.8}{\sqrt{23}} = 0.58$ Comparing the different values of k $k_{mean} = \frac{0.44 + 0.58}{2} = 0.51$ $\therefore \Delta k = 0.58 - 0.44 = 0.14$ Percentage difference = $\frac{\Delta k}{k_{mean}} \times 100\% = \frac{0.14}{0.51} \times 100\% = 27\%$ Draw conclusion based on stated criterion: The relationship is not true because there is more than 20% difference in values of k.

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2(a) d_{ave} = (0.28+0.28+0.28) /3 = <u>0.28 mm</u>

(b)(i) I = 60.0 mA
V = 0.752 V

(iii)

I / mA	V / V
66.9	0.839
72.6	0.909
78.0	0.975

(c)

(d)

3(b)(i) L = 50.1 cm

(ii) θ = 55°

(iii) Estimate $\Delta\theta \approx 3°$

Hence, percentage uncertainty = $\frac{\Delta\theta}{\theta} x100\% = \frac{3}{55} x100\%$ = **<u>5.5%</u>** (max of 2 s.f.)

(c)(ii)

Time for 10 oscillations	
t_1 /s	**t_2 /s**
18.7	18.8

Period, $T = \frac{t_1 + t_2}{20} = \frac{18.7 + 18.8}{20}$ = **<u>1.88 s</u>**

(d)

θ / °	Time for 10 oscillations		Period T / s	T^2 / s^2	cos (θ / °)
	t_1 /s	t_2 /s			
55	18.7	18.8	1.88	3.52	0.57
44	16.5	16.7	1.66	2.76	0.72
61	20.3	20.8	2.06	4.22	0.48
68	22.7	23.0	2.29	5.22	0.37
65	21.8	22.1	2.20	4.82	0.42
59	19.6	20.0	1.98	3.92	0.52

(e) Given: $T^2 = A(\cos\theta) + B$

Graph of is T^2 vs cos θ *is* plotted, gradient = A, the y-intercept = B

gradient , m = $\frac{4.90 - 3.175}{0.40 - 0.65} = -6.90$

$A \approx -6.90$ s^{-1}

Sub (0.40, 4.90) into the equation

$4.90 = (-6.90)(0.4) + B$

$B \approx 7.66$ s^{-1}

(g) There are no anomalous data points. All the data points are reasonably close to the best-fit straight line.

OR

There are no anomalous data points. All the data points are on the best-fit straight line.

OR

Point (x,y) is an anomalous data point as it is too far from the line of best fit.

(h) 1. There is difficulty in holding protractor stationary and vertically and hence there is difficulty in measuring the angle.

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	2. Difficulty in estimating the extreme or equilibrium positions for the measurement of time for n oscillations
(i)	1. Use trigonometric function to determine θ (with suitable elaboration). 2. Set up fiducial line by e.g. suspending a pendulum close to oscillating ruler but not in contact with the set-up) to provide accurate indication of extreme or equilibrium positions.

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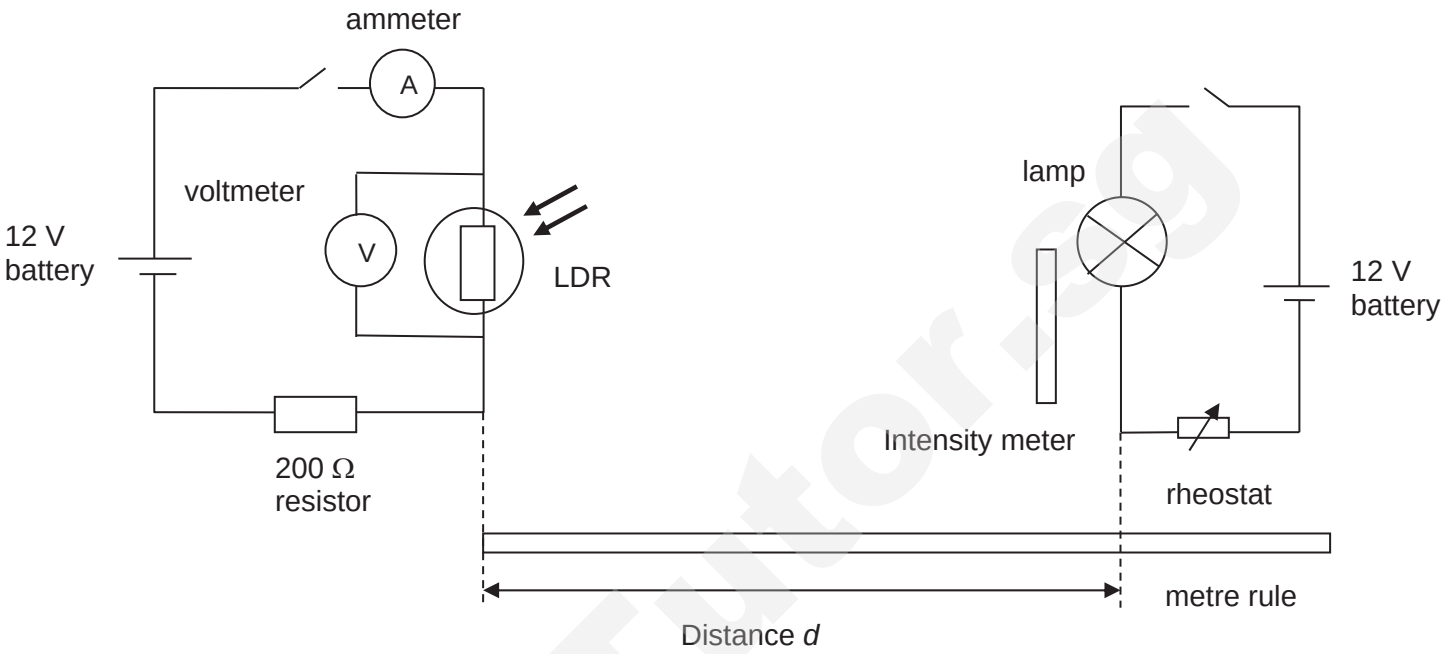
Suggested solution to Planning

Diagram



Objective:

To investigate how the resistance, *R* of the LDR depends on the distance *d* from the lamp.

Independent variable : Distance *d* from the lamp

Dependent variable : Resistance *R* of the LDR

Controlled variable : **1.** Alignment of the lamp with the LDR

2. Brightness/Intensity of the lamp/Keep output of the lamp constant

3. Ambience light intensity

Apparatus:

1. Measure the distance *d* between the lamp and the LDR using a metre rule. Set *d* = 10.0 cm

2. Measure the voltage, *V* across the LDR using a voltmeter in series. Measure the current, I through the LDR using a ammeter in series. Calculate the resistance of LDR using $R = V/I$.

3. The orientation of the LDR with respect to the lamp must be kept constant i.e the lamp must be pointing at the LDR in the same direction. The lamp and the LDR can be fixed at a particular position using adhesive tape.

4. An intensity meter is used to check whether the output of the lamp is constant during the experiment. Use a rheostat in series with the voltage supply to the lamp and adjusting the rheostat to maintain a constant current (i.e. constant intensity of light) through the lamp.

5. The experiment should be performed in a dark room so that the intensity of other light sources would not interfere with the variation of the resistance of the LDR.

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Procedure

1 Set up the apparatus as shown in the diagram above.

2 Measure the distance *d* between the lamp and the LDR

3 Close the circuits.

4 Measure the potential difference across the LDR and the current flowing LDR.

5 Record the voltmeter and the ammeter readings and calculate the resistance of the LDR.

6 Open the circuits

7 Increase the distance *d* and repeat step (2) to (6) until you have 6 sets of readings of *d*, *V, I and R.*

Analysis

1 Assume that the resistance *R* is related to the distance *d* by the equation

$$R = kd^n$$

where k and n are constants.

2 Taking lg on both sides, lg(*R*) = n lg(*d*) + lg (k).

3 Plot a graph of lg (*R*) against lg (*d*)

4 If the above relationship is true, a straight line graph will be obtained where the gradient is equal to n and the y-intercept is equal to lg(k).

Safety considerations

1 Do not look directly at the lamp. Wear sun glasses if the intensity of the lamp is too high.

2 Do not touch the lamp with bare hands. Wear gloves when handling the lamp after use.

3 Electric circuit set up must be away from sink and kept dry at all times.

4 Do not handle the electrical circuits with wet hand.

5 Ensure all the connecting wires are properly insulated to prevent any cases of electric shock.

Additional details

1 The orientation of the LDR with respect to the lamp must be kept constant i.e the lamp must be pointing at the LDR in the same direction. The lamp and the LDR can be fixed at a particular position using adhesive tape.

2 The resistance of the LDR is high and hence the current flowing in the circuit will be small. The ammeter is set to 200 mA to measure the current flowing in the circuit.

3 Take average readings of *V* and *I* by repeating the experiment with increasing and decreasing *d*.

4 The intensity meter, lamp and the LDR can be placed in a black cardboard tube/container to minimize the light from the surroundings from reaching the LDR or intensity meter.

5 The distance between the intensity meter and the lamp should also be kept constant by placing markers at their locations. The alignment/orientation of the lamp and the intensity meter is to be kept constant.

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Suggested mark scheme to Planning Question

Diagram		**[2]**
Good choice of apparatus and a clearly labeled diagram.		
- correct circuit diagram e.g voltmeter // to LDR, ammeter in series with LDR, orientation of lamp and LDR, diagram showing ruler measuring distance *d*, LDR using conventional circuit symbol, correct circuit diagram for the lamp	**D1,** **D2**	
Procedure		**[4]**
- The procedure is outlined in a clear and logical manner such that it can be followed by another person carrying out the experiment. - ***R*** **=** $\frac{V}{I}$	**P1** **P2**	
Mention of apparatus used for different measurement - **voltmeter** to measure **potential difference**, **ammeter** to measure the **current**. - **ruler** to measure **distance** *d*, **intensity meter** to measure **intensity** of lamp.	 **P3** **P4**	
Control of variables		**[2]**
- Alignment of the lamp with the LDR	**C1,** **C2**	
- Brightness/intensity of the lamp/ Keep output of the lamp constant		
- Ambience light intensity		
Note: **minus [1]** if dependent or independent variable is stated wrongly		
Analysis		**[1]**
- details of derived quantities to be calculated. Plot lg *R* vs lg *d*, y-intercept = lg k , gradient = n must be included to be awarded [1] mark	**A1**	
Safety Precaution		**[1]**
- Do not look directly at the lamp. Wear sun glasses if the intensity of the lamp is too high.		
- Do not touch the lamp with bare hands. Wear gloves when handling the lamp	**S1**	

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after use.		
- Electric circuit set up must be away from sink and kept dry at all times.		
- Do not handle the electrical circuits with wet hand.		
- Ensure all connecting wires are properly insulated to prevent any cases of electrocution.		
Any additional details		**[max 2]**
- The orientation of the LDR with respect to the lamp must be kept constant i.e the lamp must be pointing at the LDR in the same direction. The lamp and the LDR can be fixed at a particular position using adhesive tape.	**AD1**	
- A intensity meter is used to check whether the output of the lamp is constant during the experiment. The alignment/orientation of distance of the lamp and the intensity meter and the distance between the intensity metre and the lamp should be kept constant by placing markers at their locations.	**AD2**	
- The experiment should be performed in a dark room so that the intensity of other light sources would not interfere with the variation of the resistance of the LDR.		
- The resistance of the LDR is high and hence the current flowing in the circuit will be small. The ammeter is set to 200 mA to measure the current flowing in the circuit.		
- Taking average of *V* and *I* by repeating experiment with increasing *d* and decreasing *d*.		
- The intensity meter, lamp and the LDR can be placed in a black cardboard tube/container to minimize the light from the surroundings from reaching the LDR or intensity meter.		

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics

9749/1

Paper 1 Multiple Choice

21 September 2017

1 hour

Class Reg Number

Candidate Name _____

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

There are **thirty** questions in this section. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the Optical Mark Sheet (OMS).

Read very carefully the instructions on the OMS.

Write your name and class in the spaces provided on the OMS.

Shade your Index Number column using the following format:

1) **first 2 digits is your index number in class (e.g. 5th student is shaded as "05");**

2) **ignore the last row of alphabets.**

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-GM/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer all 30 questions in this paper and shade your answers on the answer sheet provided.

1 Which estimate is realistic?

A The kinetic energy of a bus traveling on an expressway is 30 000 J.

B The power of a domestic light is 300 W.

C The temperature of a hot oven is 300 K.

D The volume of air in a car tyre is 0.03 m^3.

2 A car at rest at a traffic junction starts to accelerate at 2.0 m s^{-2} when the traffic light turns green. At this moment, a truck travelling at a constant velocity of 14 m s^{-1} passes the car.

If the car is accelerating uniformly, how long will it take for the car to just overtake the truck?

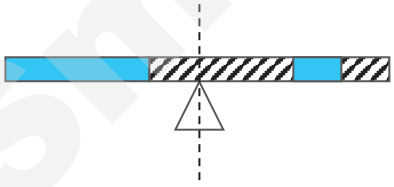
A 7.0 s **B** 14 s **C** 28 s **D** 56 s

3 Four different composite rods of uniform thickness are to be balanced horizontally on a knife-edge. Each rod is made up of 50% material A and 50% material B, where B is denser than A. The mid-point of each composite rod is indicated by a dotted vertical line.

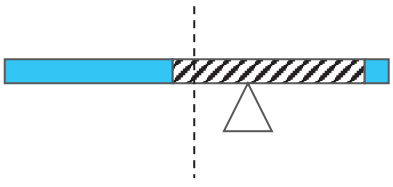
Legend: Material A Material B

Which scenario is unlikely to occur?

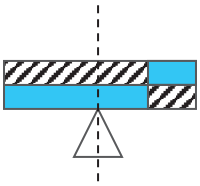
A



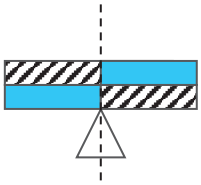
B



C



D



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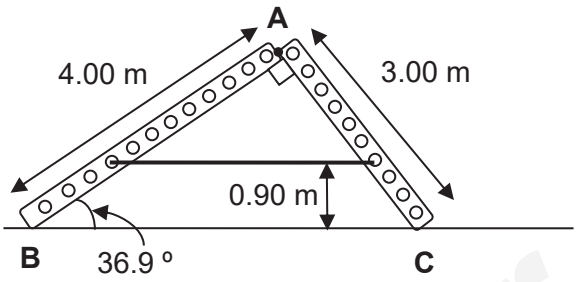
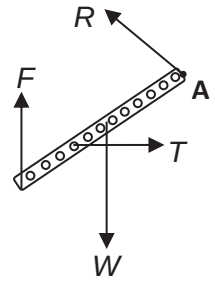
4 Two uniform ladders, 4.00 m and 3.00 m long, weighing 390 N and 290 N respectively are hinged at point **A** (90º apart) and tied together by a horizontal rope 0.90 m above the floor, as shown below. Assume the floor is freshly waxed and frictionless.

The contact force *F* at point **B** is 317 N.

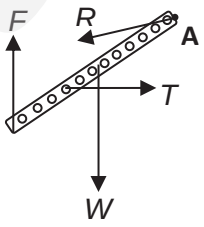


Which of the following diagrams shows the correct forces *F*, weight *W* and tension of rope *T* and reaction force *R* acting at point **A** of the 4.00 m ladder?

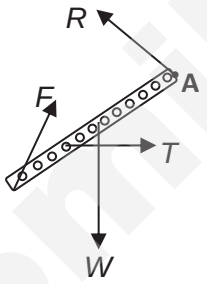
A



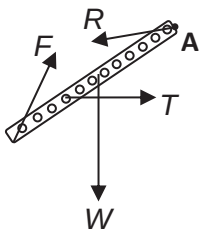
B



C



D



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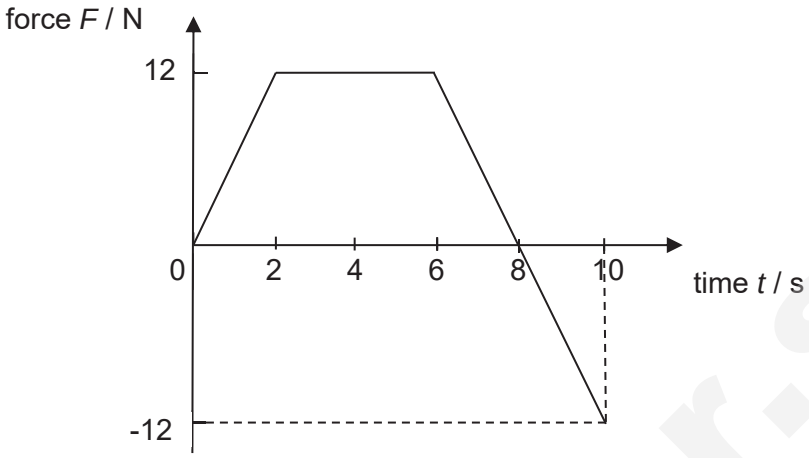
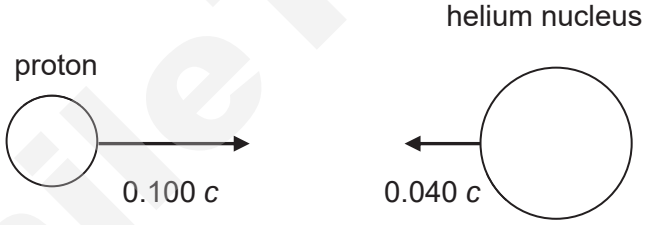
5 A body of mass 300 g initially at rest is acted on by a force F which varies with time t as shown in the diagram below.



What is the speed of the body at the 10th second?

A 200 m s^{-1} **B** 240 m s^{-1} **C** 260 m s^{-1} **D** 280 m s^{-1}

6 A proton (mass 1 u) travelling with velocity +0.100 c collides elastically head-on with a helium nucleus (mass 4 u) travelling with velocity -0.040 c.



What are the velocities of each particle after the collision?

	proton	helium nucleus
A	+0.004 c	+0.064 c
B	-0.004 c	+0.064 c
C	+0.124 c	+0.016 c
D	-0.124 c	+0.016 c

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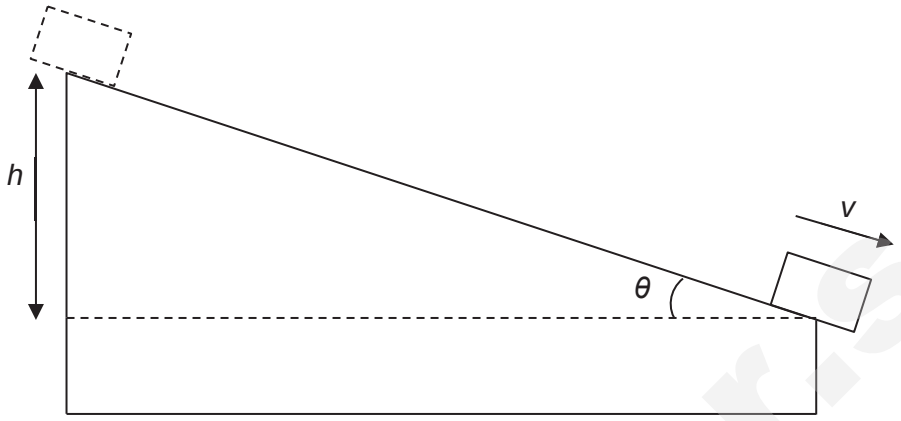
7 A box of mass *m* slides down a smooth ramp from rest. At time *t*, the box has slid down height *h* and is moving with speed *v*. The slope makes an angle *θ* with the horizontal, as shown in the diagram below.

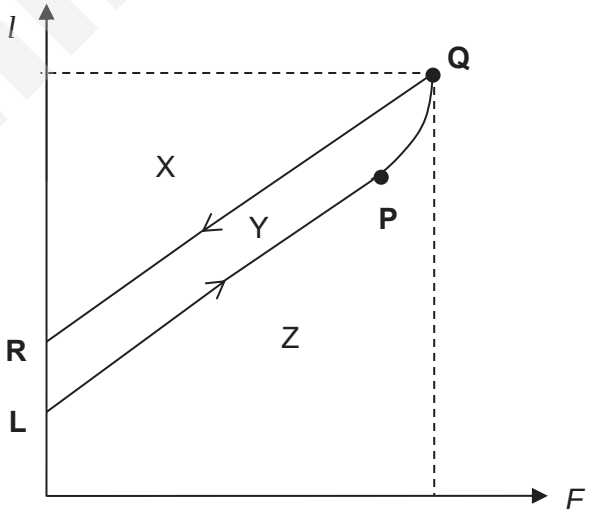


Which expression represents the rate of change of work done by gravitational force of the box at time *t*?

A mgv **B** $\dfrac{mgh+\frac{1}{2}mv^2}{t}$ **C** $mg\sin\theta\left(\dfrac{h}{t}\right)$ **D** $mg\sin\theta\sqrt{2gh}$

8 A spring is stretched by a varying force *F*, causing its length *l* to increase as shown by the line **LPQ** on the graph. The force is then gradually reduced to zero and the relationship between force and length is indicated by the line **QR**.

Which area represents the elastic potential energy stored in the spring at **Q**?



A X **B** X + Y **C** Y + Z **D** Z

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9 Javier noticed that his watch is inaccurate as the minute hand of his watch travels at an angular speed of 1.744×10^{-3} rad s^{-1}. What is the time difference between his watch and an accurate clock 24 hours after he has synchronised it?

A 0.55 seconds

B 1.1 seconds

C 66 seconds

D 130 seconds

10 A man is in a spacecraft that is orbiting around a planet.

Which of the following statements is true?

A The man is on the ground of the spacecraft so as to provide for the centripetal force required for him to orbit the planet.

B The man is on the ground of the spacecraft as the gravitational force by the planet on the man attracts the man to the ground of the spacecraft.

C The man is floating in the spacecraft as the gravitational force by the planet on the man balances the centripetal force on the man.

D The man is floating in the spacecraft as the spacecraft and the man are experiencing the same centripetal acceleration.

11 Satellite A of mass m orbits a planet of radius R at a height R above the surface of the planet with kinetic energy, E_k.

What is the kinetic energy of satellite B of mass $2m$ that orbits the same planet at a height $2R$ above the surface of the planet?

A E_k **B** $\frac{2}{3}E_k$ **C** $\frac{4}{3}E_k$ **D** $4\,E_k$

12 A mass of 0.40 kg undergoing simple harmonic motion has a total energy of 5.0 J and amplitude 0.25 m. What is its period?

A 0.016 s **B** 0.050 s **C** 0.31 s **D** 0.63 s

13 Which one of the following is an effect of an increase in damping in a forced oscillation?

A amplitude at resonance increases

B the natural frequency at resonance increases

C the total energy of the system increases

D the period of the driven oscillator at resonance increases

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14 A musical organ produces notes by blowing air into a set of pipes that are open at one end and closed at the other.

What is the lowest frequency of sound produced by a pipe of length 2 m?
(The speed of sound in the pipe is 320 m s^{-1}.)

A 20 Hz **B** 40 Hz **C** 80 Hz **D** 160 Hz

15 Diffraction can be observed when a wave passes an obstruction. The diffraction effect is greatest when the wavelength and the obstruction are similar in size.

For waves travelling through air, what is the combination of wave and obstruction that could best demonstrate diffraction?

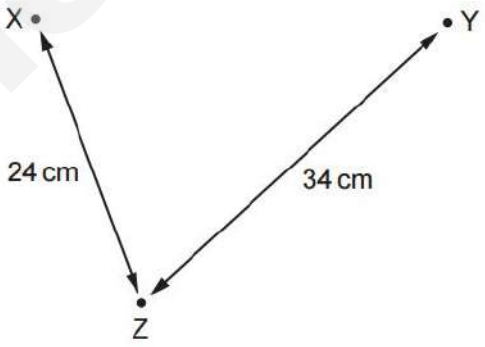
A visible light waves passing through an entrance of a classroom door

B sound waves passing through a human hair

C radio waves passing through a copper wire

D microwaves passing through a steel post

16 Wave generators at points X and Y produce waves of the same wavelength. At point Z, the waves from X have the same amplitude as the waves from Y. Distances XZ and YZ are as shown.



When the wave generators operate in phase, the amplitude of oscillation at Z is zero.

What could be the wavelength of the waves?

A 2 cm **B** 3 cm **C** 4 cm **D** 6 cm

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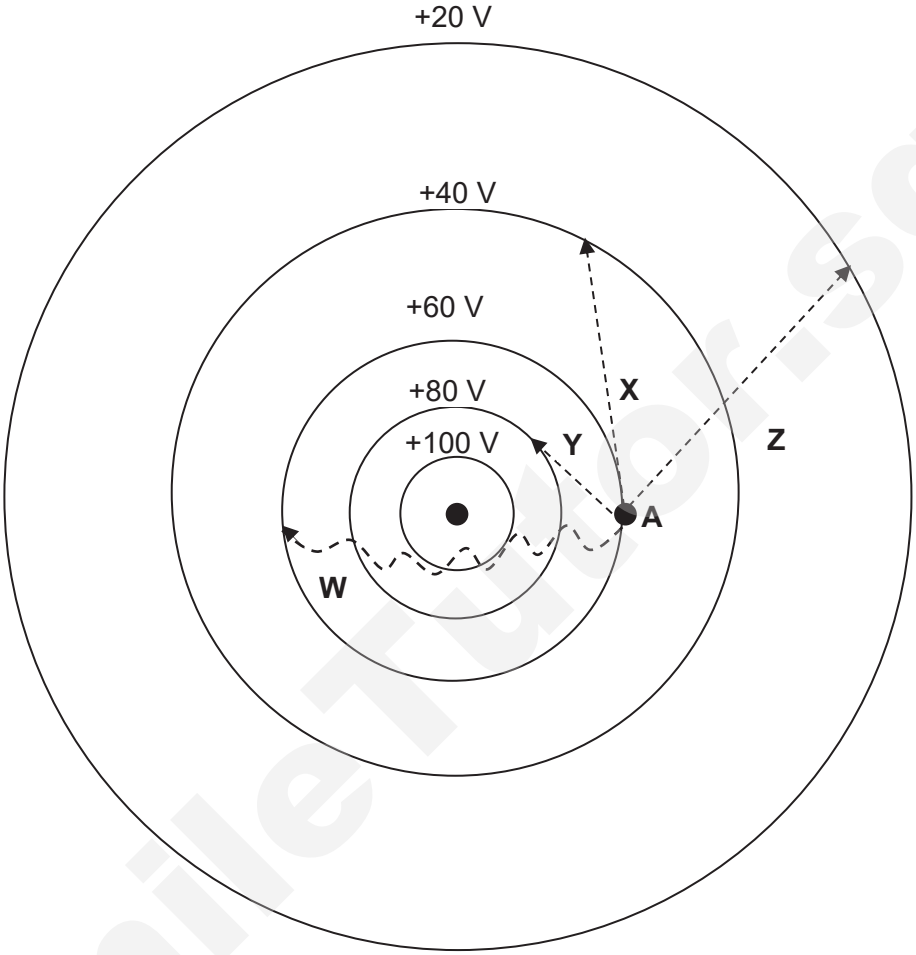
17 The diagram below shows the equipotential lines around a point charge. Another particle of charge +2*e* was then brought from position **A** which lies on the equipotential line of +60 V to other positions on other equipotential lines through various paths.



Which of the following statements is true?

A The work done by the electric field in bringing the charge through path **W** is the greatest.

B The work done by the electric field in bringing the charge through paths **X** and **Y** are the same.

C The work done by the electric field in bringing the charge through path **Z** is the greatest.

D The work done by the electric field for all four paths are non-zero.

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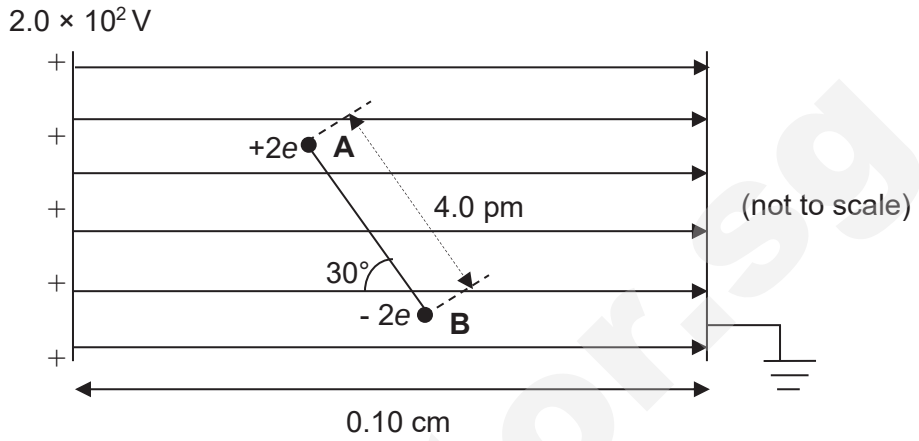
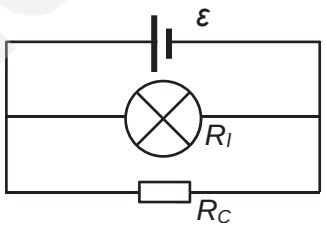
18 Two ions **A** and **B,** at a distance of 4.0 pm apart, are linked to form a molecule. They are situated between a pair of charged parallel plates placed a distance of 0.10 cm apart. The left plate has a potential of 2.0×10^2 V and the right plate is earthed. The line joining **A** and **B** is at an angle of 30° to the direction of the electric field as shown in the diagram below.



What is the torque on the molecule **AB**?

A 2.2×10^{-25} N m **B** 1.3×10^{-25} N m **C** 2.6×10^{-25} N m **D** 5.1×10^{-25} N m

19 The figure below shows a lamp of resistance R_l and a device of resistance R_C being powered by an electrical source, ε.



Which expression gives the fraction of the total power delivered to the lamp?

A $\frac{R_C}{R_l + R_C}$ **B** $\frac{R_l}{R_l + R_C}$ **C** $\frac{R_C}{R_l}$ **D** $\frac{R_l}{R_C}$

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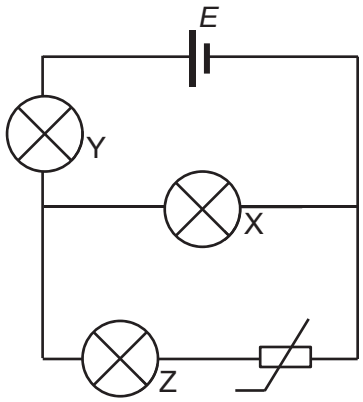
20 A cell of e.m.f. *E* is connected to three identical lamps X, Y, and Z, and a negative temperature coefficient thermistor as shown in the figure below.



If the thermistor is heated up, which statement about the change in brightness of bulbs X and Y is true?

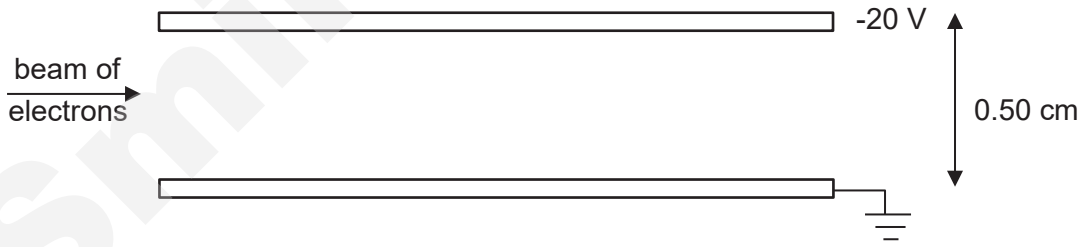
A Both X and Y become brighter.

B Both X and Y become dimmer.

C Y becomes brighter, but X dims.

D X becomes brighter, but Y dims.

21 A beam of electrons, travelling horizontally to the right with a speed, *v*, passes between two horizontal charged parallel metal plates separated by 0.50 cm. The potential of the upper plate is -20 V and the lower plate is earthed.



There is no deflection of the beam because of the presence of a uniform magnetic field in the region between the plates.

What is the magnitude of the magnetic field and in which direction must this magnetic field be?

	magnitude	direction
A	4000 / *v*	out of the paper
B	4000 / *v*	into the paper
C	20 / *v*	out of the paper
D	20 / *v*	into the paper

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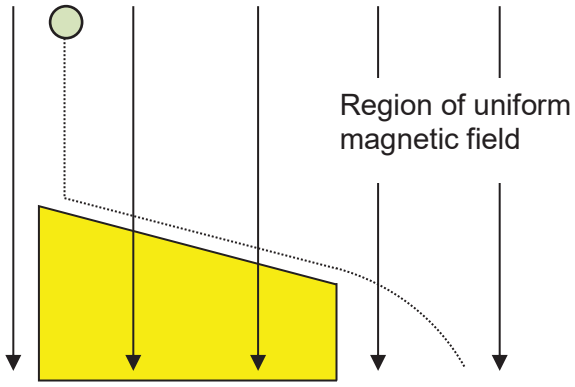
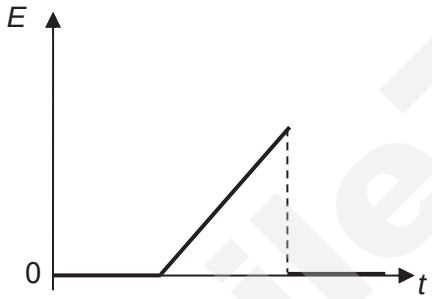
22 In a region of uniform magnetic field, a metal rod falls vertically from rest and lands on to a slope. It continues to roll down the slope and launches off the slope as shown in the diagram.

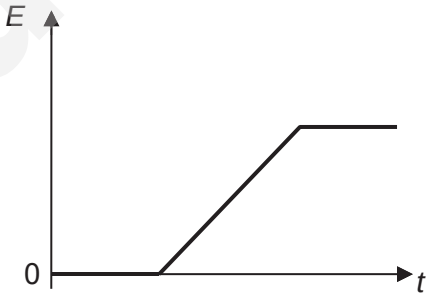


Which graph best shows the variation with time *t* of the e.m.f. *E* induced in the rod, from the time it is released?

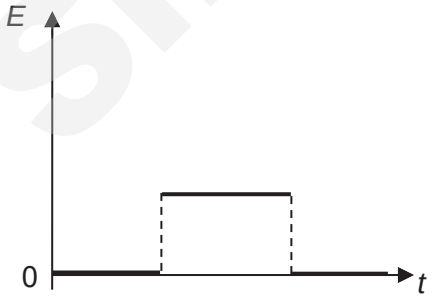
A



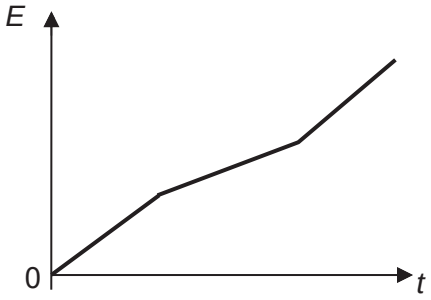
B



C



D



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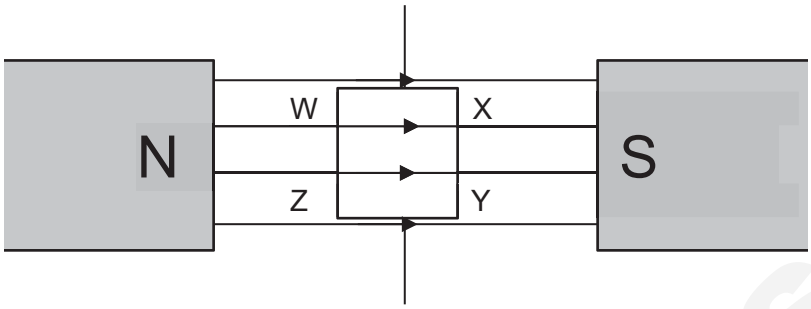
23 In an electric motor, a rectangular coil WXYZ carrying current, I, has 20 turns and is in a uniform magnetic field of flux density 0.80 T.



The lengths of sides XY and ZW are 0.17 m and of sides WX and YZ are 0.11 m. The maximum torque provided by the motor is 1.35 N m.

What is the current, I, in the rectangular coil?

A 4.5 A **B** 9.0 A **C** 45 A **D** 90 A

24 The secondary coil of an ideal transformer delivers a root-mean-square (r.m.s.) current of 2.5 A to a load resistor of resistance 8.0 Ω. The r.m.s. current in the primary coil is 10 A.

What is the r.m.s. potential difference across the primary coil?

A 3.5 V **B** 5.0 V **C** 57 V **D** 80 V

25 A gas cylinder is fitted with a safety valve which releases a gas when the pressure inside the cylinder reaches 2.0×10^6 Pa. Given that the maximum mass of this gas the cylinder can hold at 10 °C is 15 kg, what would be the maximum mass at 30 °C?

A 5 kg
B 14 kg
C 16 kg
D 45 kg

26 Which of the following statement about internal energy is correct?

A Internal energy of a system depends only on its temperature.
B When internal energy of the system increases, its temperature always rises.
C The internal energy of a system can be increased without transfer of energy by heating.
D When two systems have the same internal energy, they must be at the same temperature.

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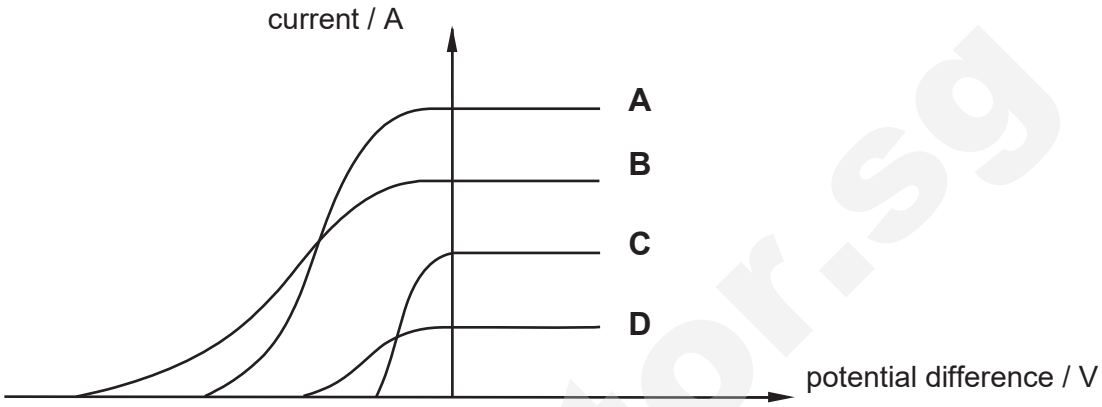
27 The figure below shows the currents observed in a photocell circuit as a function of the potential difference between the plates of the photocell when light beams **A**, **B**, **C** and **D** were each directed in turn at the cathode.

Which of the beams has the lowest wavelengths?



28 The uncertainty in the position of an electron is 50 nm. What is the minimum uncertainty in its velocity?

A $7.9\ \text{m s}^{-1}$

B $8.0\ \text{m s}^{-1}$

C $1.5 \times 10^{3}\ \text{m s}^{-1}$

D $1.5 \times 10^{4}\ \text{m s}^{-1}$

29 Which one of the following combinations of radioactive decay results in the formation of an isotope of the original nucleus?

A one alpha particle and four beta particles

B two alpha particles and one beta particle

C four alpha particles and one beta particle

D one alpha particle and two beta particles

30 A detector is used for monitoring an α-source and a reading of 300 counts is observed. After a time equal to the half-life of the α-source, the reading has fallen to 155 counts. If a 5 mm thick lead sheet is inserted between the α-source and the detector, the reading would probably be

A 0 counts **B** 5 counts **C** 10 counts **D** 20 counts

End of Paper

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics

9749/2

Paper 2 Structured Questions

15 September 2017

2 hours

Class | Reg Number

Candidate Name _____

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

Examiner's Use	
Q1	/9
Q2	/10
Q3	/8
Q4	/12
Q5	/9
Q6	/12
Q7	/20
Deduction	
Total	/80

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Data

speed of light in free space	C	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-GM/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 **(a)** Use Newton's laws of motion to explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

.....

.....

.....

..... [3]

(b) A small mass m and a heavy mass M are connected to the ends of an inextensible string. The string is threaded through a glass tube as shown in Fig. 1.1. The tube is then held by a student and is whirled so that the mass m rotates with a constant radius r at a frequency of 175 revolutions per minute. Given that m = 0.30 kg and M = 0.90 kg.

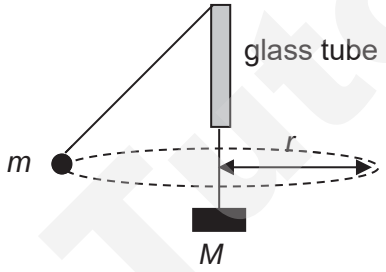

Fig. 1.1

(i) Calculate the resultant force acting on the mass m.

resultant force = ... N [2]

(ii) Hence, calculate the radius r of the circle.

r = ...m [2]

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(iii) Explain whether it is possible for the small mass m to be whirled in such a way that the string attached to it becomes horizontal.

.....

.....

.....

.....

.....

..... [2]

2 **(a)** Define *gravitational potential* at a point.

.....

.....

..... [2]

(b) The Sun may be assumed to be an isolated uniform sphere with a mass M_S concentrated at its centre. The Earth of mass M_E orbits the Sun in a circular path of radius R as shown in Fig. 2.1.

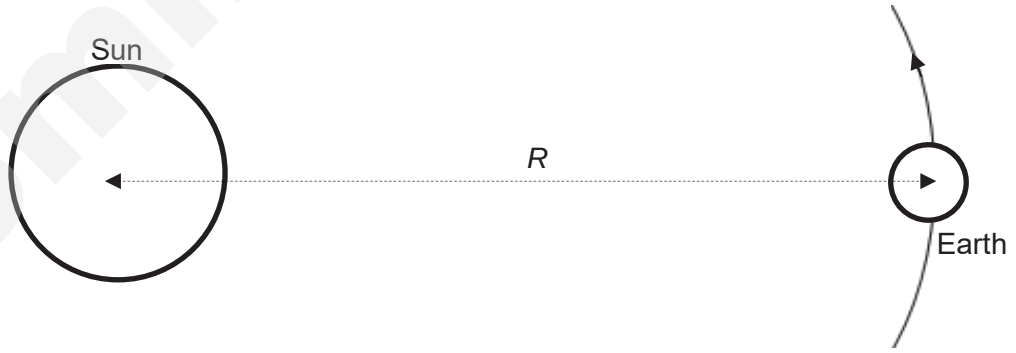

Fig. 2.1

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(i) For the Earth in orbit, derive an expression for its total energy in terms of M_S, M_E and R. Explain your working clearly. [4]

(ii) Explain what does negative total energy imply about the system that comprises of the Sun and the Earth.

……..

……..

…… [2]

(c) An unpowered artificial satellite is orbiting around the Sun along the same radial line from the Sun to the Earth as shown in Fig. 2.2.

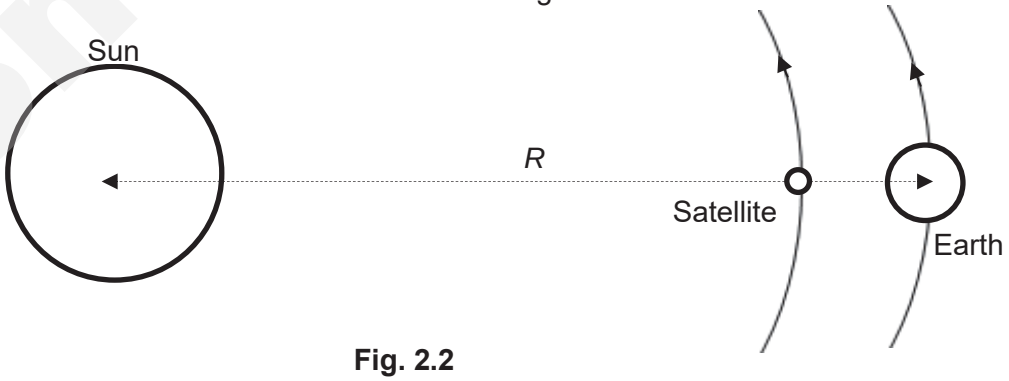

Fig. 2.2

Explain how it is possible for the satellite and the Earth to have the same orbital period but different orbital radius about the Sun.

……

……

…… [2]

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3 (a) State the defining equation for simple harmonic motion and define any symbols used.

.....

.....

..... [2]

(b) A frictionless trolley of mass m is held on a horizontal surface by means of two identical springs, each of spring constant k. The springs are attached to fixed points, as illustrated in Fig. 3.1.

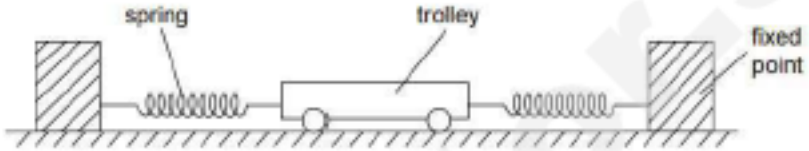

Fig. 3.1

When the trolley is in equilibrium, the extension of each spring is e.

The trolley is displaced a small distance x to the right along the axis of the springs. Both springs remain extended.

(i) Show that the magnitude F of the restoring force acting on the trolley is given by

$$F = 2kx$$ [2]

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(ii) The trolley is then released. Derive an expression for the acceleration a of the trolley in terms of k, x and m. Explain your working. [2]

(iii) The mass m of the trolley is 1500 g and the spring constant k is 0.80 N cm^{-1}. Determine the frequency of oscillation of the trolley.

frequency = …….. Hz [2]

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4 **(a)** A rectangular coil is place at the centre of the solenoid with its plane perpendicular to the axis of the solenoid as shown in Fig. 4.1.

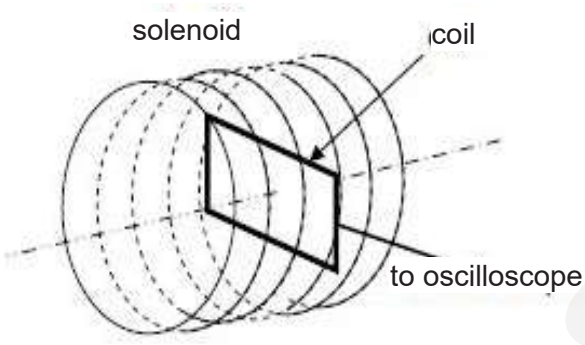

Fig. 4.1

The ends of the coil are connected to a cathode ray oscilloscope.

An alternating current is passed through the solenoid and its variation with time is shown in Fig. 4.2.

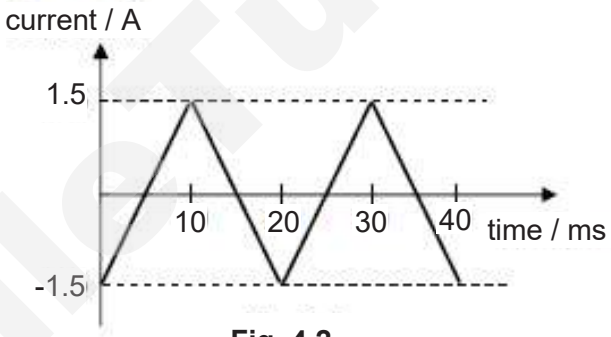

Fig. 4.2

(i) State

1. Faraday's law of electromagnetic induction,

……

……

……

2. Lenz's law.

……

……

…… [2]

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(ii) Hence, explain why there is an induced e.m.f. in the rectangular coil.

……..

……..

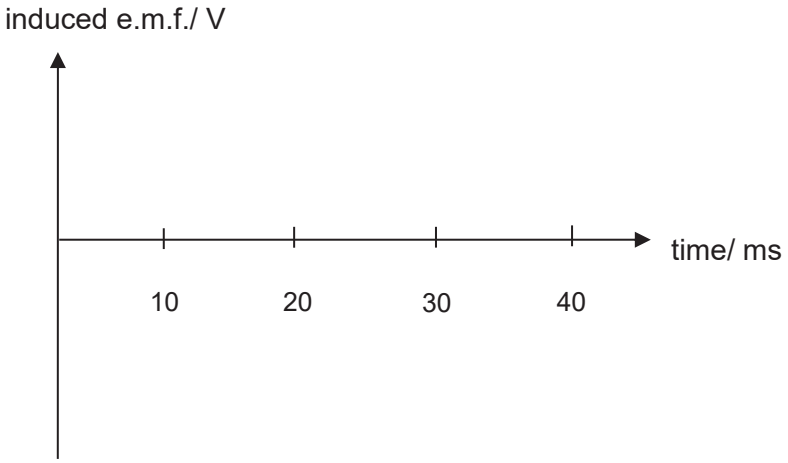
……..

…… [2]

(iii) The solenoid of length 0.50 m, has 400 turns and a cross-sectional area of 5.0×10^{-3} m^2. The rectangular coil has 8 turns with dimensions 0.010 m by 0.020 m. Calculate the magnitude of the maximum induced e.m.f. in the coil.

e.m.f. = ……V [3]

(iv) Sketch the variation with time of the induced e.m.f. in the coil in the axes provided. [2]



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(v) A resistor of 2.0 Ω is connected in parallel to the oscilloscope connected to the coil in Fig. 4.1. Calculate the maximum power across the resistor.

maximum power =…….. W [2]

(vi) Suggest one change to the set-up in Fig. 4.1 to increase the induced e.m.f in the coil.

……..

……. [1]

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5 **(a)** Explain one advantage of using alternating current when transmitting electrical energy.

……

……

…… [2]

(b) An a.c. power supply is connected to a resistor *R*, a diode and a battery of e.m.f. 12.0 V as shown below in Fig. 5.1.

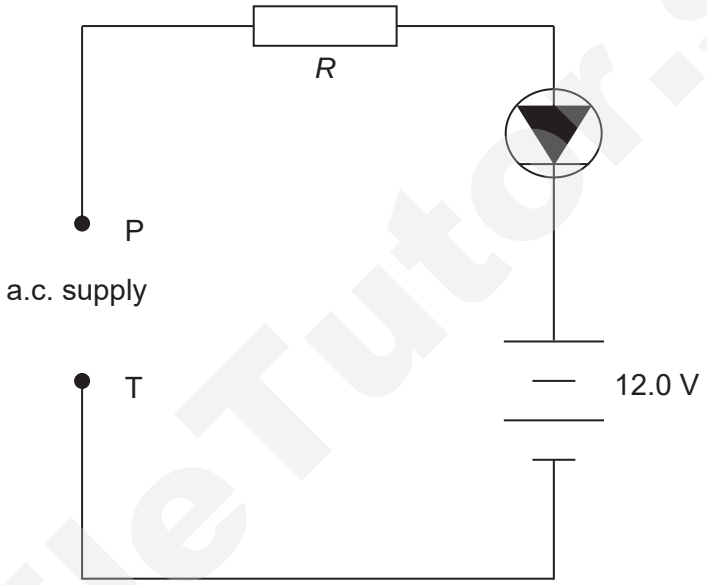

Fig. 5.1

The variation of the potential of P with respect to T, V_{PT}, is as shown in Fig. 5.2.

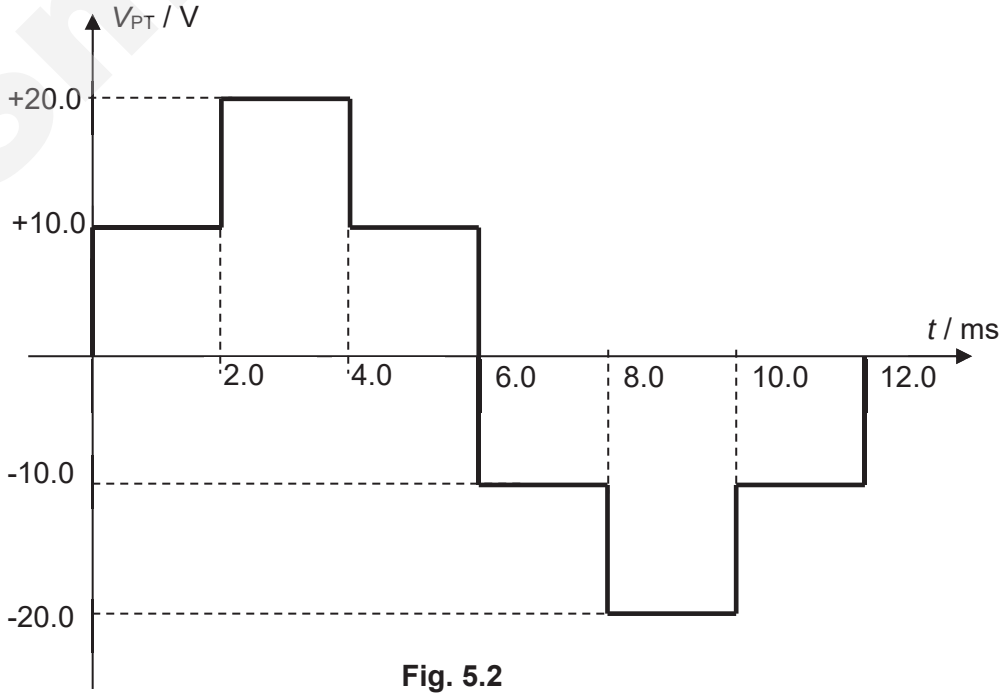

Fig. 5.2

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(i) Calculate the root-mean-square potential difference V_{rms} across points P and T.

V_{rms} = …… V [2]

(ii) Determine the potential difference across resistor *R* when

1. V_{PT} = +10.0 V

potential difference = …… V [1]

2. V_{PT} = +20.0 V

potential difference = …… V [2]

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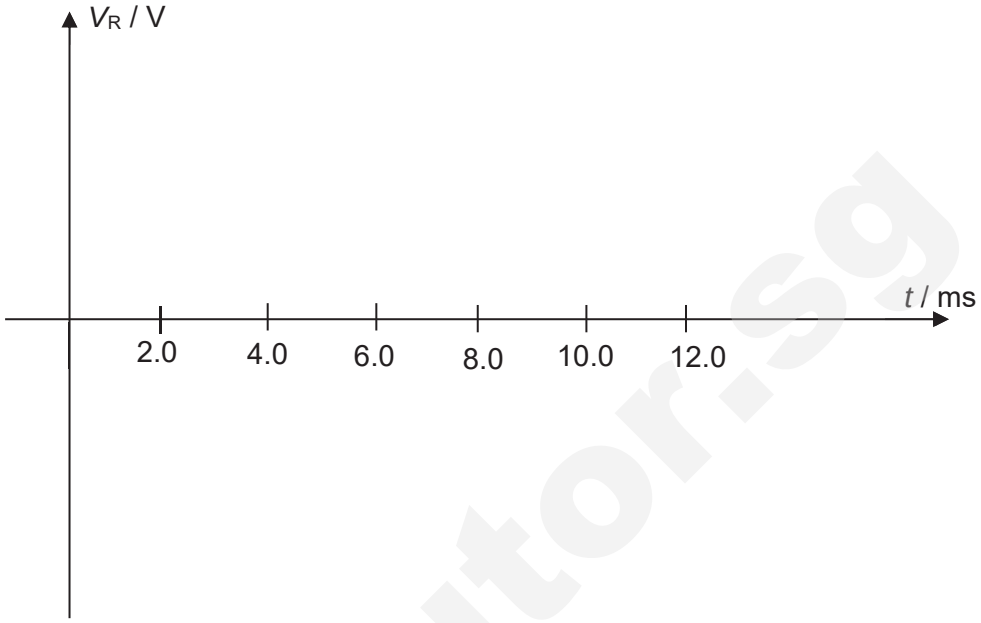
(iii) Hence, sketch in the following axes the variation with time of the potential difference across R (V_R). [2]



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6 (a) Three constant pressure gas thermometers contain an identical type of gas at different pressures. These three thermometers are then used to determine the temperature T of an object as well as the temperature at triple point of water. The readings of each thermometer are tabulated in Fig. 6.1.

	Readings at temperature T		Readings at triple point of water	
	Pressure P / Pa	Volume V / cm^3	Pressure P / Pa	Volume V / cm^3
Thermometer 1	100 000	503.30	100 000	398.53
Thermometer 2	50 000	1006.20	50 000	798.19
Thermometer 3	10 000	5031.50	10 000	3997.20

Fig. 6.1

(i) Determine the value of the unknown temperature T measured by Thermometer 1. Leave your answer to 5 significant figures.

temperature T = ... K [3]

(ii) The values of T measured by Thermometer 2 and Thermometer 3 are 344.34 K and 343.84 K respectively. Explain why the values of T determined by the thermometers do not agree with each other.

.....

.....

..... [1]

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(iii) Explain how, by using a graph of the thermodynamic temperature T against pressure of the gas P of the constant pressure gas thermometers, the true value of T can be found.

Sketch the graph to illustrate your answer. Accurate plotting is not required.

.....

.....

..... [3]

(b) **(i)** Based on the kinetic theory of ideal gas, explain how evaporation of perspiration helps to cool a person.

.....

.....

.....

..... [2]

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(ii) A person expends about 350 W of power while running a marathon. Only 15% of that energy is delivered to the muscles and the remaining energy is mainly removed from the body through perspiration. The bodily fluid has a latent heat of vaporisation of 2.41×10^6 J kg^{-1}.

Determine the volume of bodily fluid lost per hour.

volume of fluid lost per hour = ……..m^3 hr $^{-1}$ [3]

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7 A deep foundation is a type of foundation which transfers the downward forces from a building to the earth further down from the surface. One type of deep foundation is pile foundations. Pile foundations are relatively long and slender members constructed by drilling-in tubes to the required depth – the tubes being filled with concrete before withdrawal. A sketch of how the column and piles system is shown in Fig. 7.1.

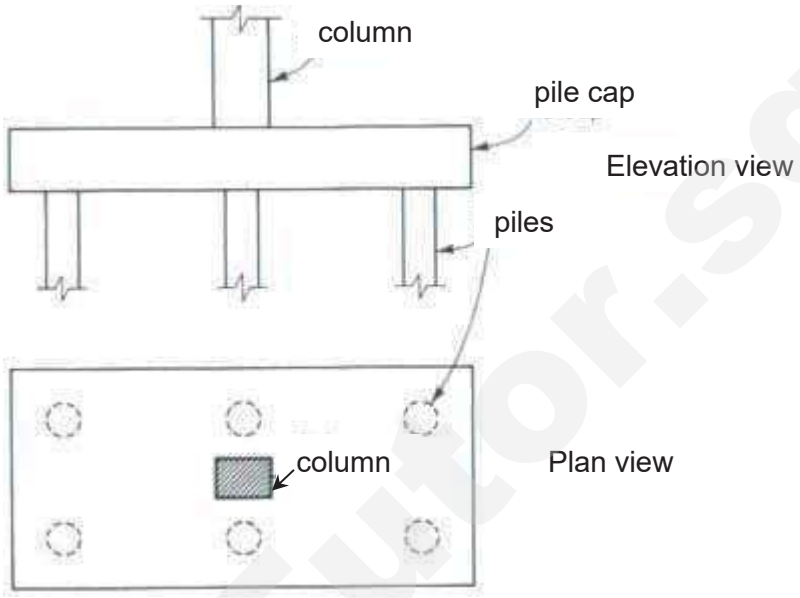

Fig. 7.1

In a construction site, some of the installed piles are selected to be tested to verify the designed soil parameter and design models.

(a) One such test is called static pile load test as shown in Fig. 7.2. A jack pushes up on the loading platform. Reaction to the jack provides the force (actual load) acting on the test pile.

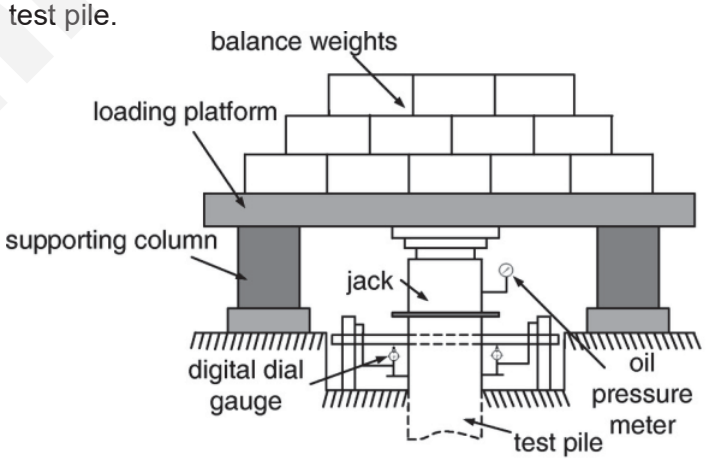

Fig. 7.2

The ultimate load-carrying capacity Q_u of a pile is designed and given by the equation (taking into consideration varying underground soil conditions):

$$Q_u = Q_p + Q_s$$

where Q_p = end (tip) resistance of the pile
Q_s = shaft resistance of the pile (frictional resistance along the length of pile)

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The results of one of the actual load tests are shown in Table 7.1. One ton is equivalent to 1000 kg of mass.

Actual Load (tons)	Q_p (tons)	Q_s (tons)	Elastic settlement (mm)	$\frac{Q_s}{\text{Actual load}}$ (%)
0	0	0	0	0
5	1.5	3.5	-1.08	70
10	2.0	8.0	-2.12	80
20	4.5	15.5	-4.08	
30	6.5	23.5	-6.58	
40	10.3	29.8	-10.36	74
50	16.0	34.0	-16.04	68
60	25.5	34.5	-25.51	58

Table 7.1

The load-settlement graph is expected to be a curve.

(i) Fill in the blanks in Table 7.1. [1]

(ii) Plot the remaining point in Fig. 7.3 and sketch the line of best fit for the actual load-settlement graph. [2]

(iii) Estimate the settlement of the pile if the actual load is 55 tons.

settlement = …….. mm [1]

(iv) Estimate $\frac{Q_S}{\text{Actual load}}$ if the actual load is 55 tons. State your assumption/s made.

$\frac{Q_S}{\text{Actual load}}$ = ……..%

Assumption/s: ……...

…..…… [2]

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(v) Suggest what is meant by elastic settlement.

……

…… [1]

(vi) Using appropriate Newton's laws, explain how the actual load acts on the pile while the jack pushes up on the loading platform.

……

……

…… [2]

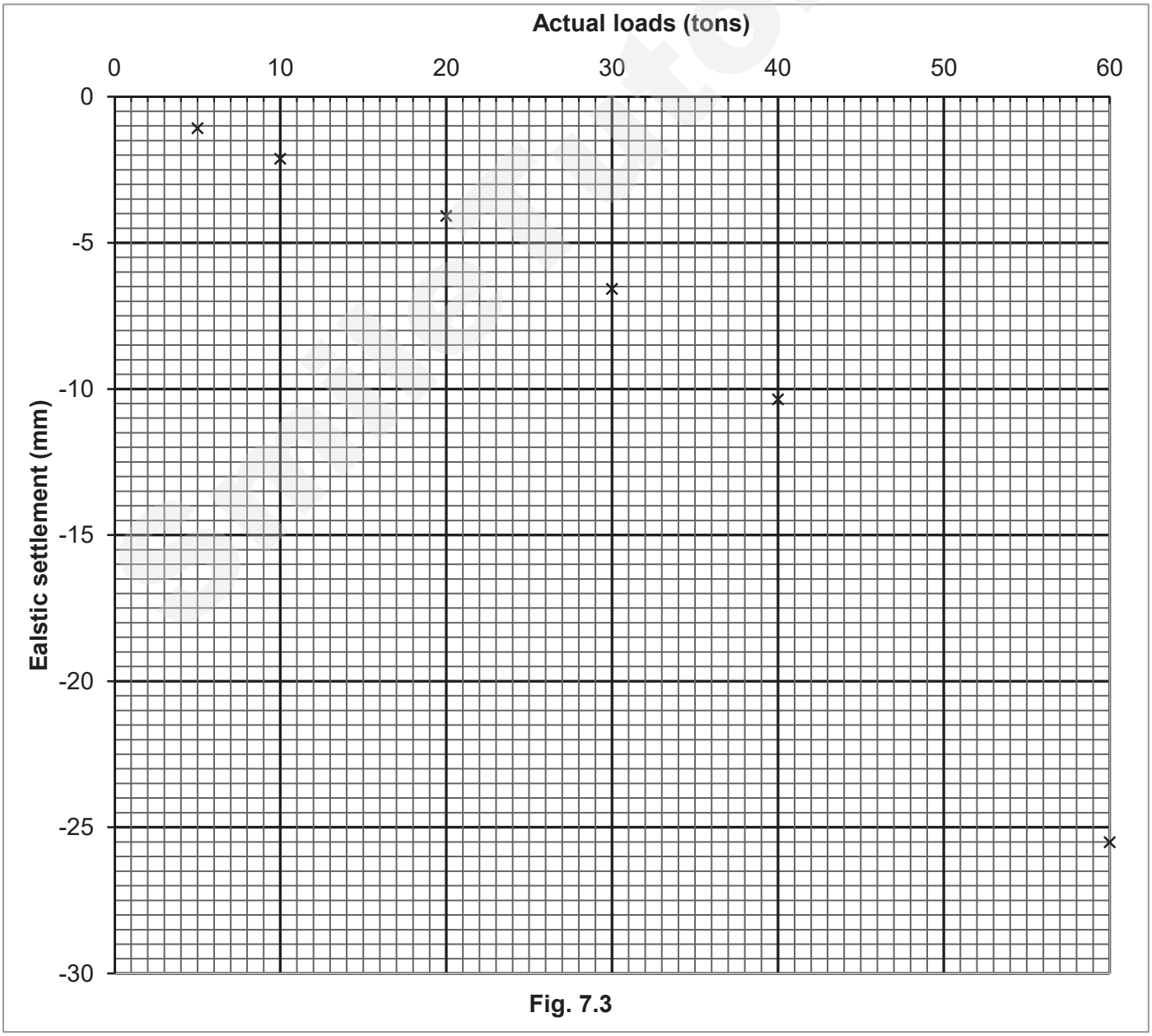

Fig. 7.3

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(vii) Calculate the upthrust on the pile if the last 10 m of a 800 mm diameter pile is submerged in the underground water. The density of underground water is 1050 kg m^{-3}.

upthrust = …….. N [2]

(viii) A large factor of safety of 4.0 is considered in some pile design. For example, a 15-ton column is supported by a pile designed with a load carrying capacity of 60 tons. Suggest why such large factor of safety is considered.

……

…… [1]

(b) Another pile test, dynamic load pile test is also conducted. In this test, a dynamic load (a falling hammer) is applied to the pile head. The acceleration and strain on the pile head is recorded through connection cable to computer software to process the information so as to estimate the pile capacity in terms of shaft resistance and tip resistance of the pile. A typical setup is shown in Fig. 7.4.

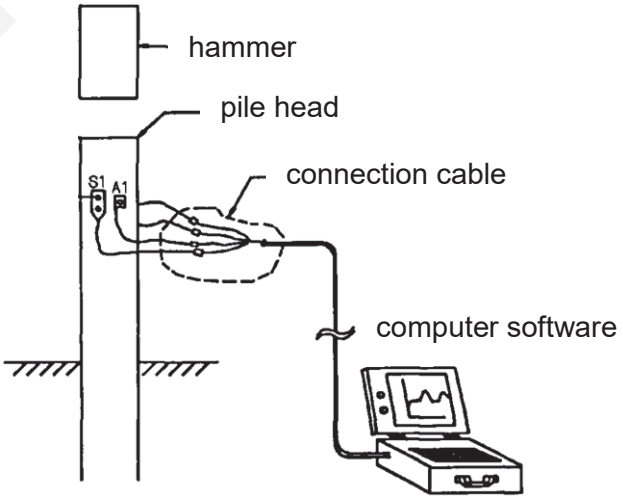

Fig. 7.4

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(i) A 600 kg hammer is dropped from rest at a height of 30.0 cm above the pile head. Calculate the energy input to the pile head as the hammer is dropped from rest.

energy input = ……..J [2]

(ii) After the hammer is dropped, a wave is sent down a 30.5 m deep pile and reflected back to the pile head. Calculate the theoretical time taken for the wave to travel down and up the pile when the velocity of the wave is 4000 m s^{-1}.

theoretical time taken = …….. s [1]

(iii) The recorded time taken was found to be smaller than that in **(b)(ii)**. Suggest a possible reason for this.

……

…..……. [1]

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(iv) Part of the information required for software analysis is the input of Young's modulus of the concrete pile, $E = \frac{\rho c^2}{k}$

where ρ is weight per unit volume of concrete = (23.5 ± 0.4) kN m^{-3}
c is the wavespeed = (4000 ± 400) m s^{-1}
k is the gravitational acceleration of 9.81 m s^{-2}.

Calculate E with its associated uncertainty. Include the unit with your answer.

E = …….. ±…….…… [4]

End of Paper

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics 9749/3

Paper 3 Longer Structured Questions **18 September 2017**

2 hours

Class Reg Number

Candidate Name _____

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name and class on all the work you hand in. Write in dark blue or black pen on both sides of the paper. You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one hour and half hours on Section A and half an hour on Section B.

Write your answers on this question booklet in the blanks provided.

Examiner's Use		Percentage
Subtotal P1	/30	/15
Subtotal P2	/80	/30
Paper 3		
Q1	/8	
Q2	/4	
Q3	/10	
Q4	/5	
Q5	/7	
Q6	/12	
Q7	/14	
Q8	/20	
Q9	/20	
Deductions for P3		
Subtotal P3	/80	/35
Subtotal P4	/55	/20
Grand total		/100

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-GM/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** One equation used in theory for gas flowing through small diameter tubes at low pressures is

$$Q = \frac{kr^3(p_1 - p_2)}{l}\sqrt{\frac{M}{RT}}$$

where k is a dimensionless constant,
r is the radius of the tube,
p_1 and p_2 are the pressures at each end of the tube of length l,
M is the molar mass of the gas (unit: kg mol^{-1}),
T is the thermodynamic temperature.

Determine the base units of Q.

base units of Q = ... [3]

(b) A cylindrical thermos flask is used to store hot water. The internal diameter and depth of the thermos flask are measured to be (8.40 ± 0.01) cm and (21.5 ± 0.1) cm respectively.

(i) State the instrument used to measure its diameter and a systematic error that can occur with the use of this instrument.

.....

..... [2]

(ii) Determine the volume of the thermos flask with its associated uncertainty.

volume = ...±.....cm^3 [3]

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2 **(a)** Define the following:

(i) *pressure* ;

.....

.....

(ii) *density of a substance*.

.....

..... [1]

(b) Hence, from the above definitions, derive an equation for the pressure p exerted by a fluid of density ρ_f, at a depth h in the fluid, in terms of ρ_f, h and the acceleration of freefall g. Define any other symbols which you may use in your derivation. [3]

3 **(a)** State the property of a body that resists change in motion.

..... [1]

(b) Define *impulse*.

.....

..... [1]

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(c) A soldier, together with his machine gun and bullets, has a combined mass of 90 kg. He stands at rest on a pair of ice skating blades and fires 10 bullets horizontally within 2.0 s in the forward direction. Each bullet has a mass of 10 g and leaves the gun with a speed of 750 m s^{-1}.

Assume there is no friction between the blades and the ground.

(i) Calculate the soldier's speed just after he fired the 10th bullet.

speed = …….. m s^{-1} [3]

(ii) Calculate the average force exerted on the soldier and his machine gun.

average force = ……..N [2]

(iii) One of the bullets hits a stationary block on a horizontal platform. The impact causes the block to slide along the platform with the bullet embedded in it. The block experiences a constant frictional force throughout its motion and comes to a complete stop after a distance *x*.

1. State the type of collision between the bullet and the block.

…..……. [1]

2. State and explain how *x* changes if the platform is inclined upwards.

……..

……..

…..……. [2]

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4 **(a)** Unpolarised light with an intensity of I_o = 32 W m^{-2} is incident on a pair of polarisers. The first polariser has its polarising axis aligned at 50° clockwise from the vertical. The second polariser has its polarising axis aligned at 20° clockwise from the vertical.

(i) State the intensity of the light when it emerges from the first polariser.

intensity = …… W m^{-2} [1]

(ii) Calculate the intensity of the light when it emerges from the second polariser.

intensity = …… W m^{-2} [2]

(b) Some recently released films have enabled viewing in three dimensions (3D). This can be done using two superimposed polarised images on the screen. One of the images is the scene as viewed by a left eye and the other as viewed by a right eye.

Explain how the images on the screen need to be polarised and how the spectacles of the cinema-goer also need to be polarised.

……

……

……

…… [2]

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5 **(a)** State the Principle of Superposition.

…….....

…….....

…….. [1]

(b) A laser is placed in front of two slits as shown in Fig. 5.1.

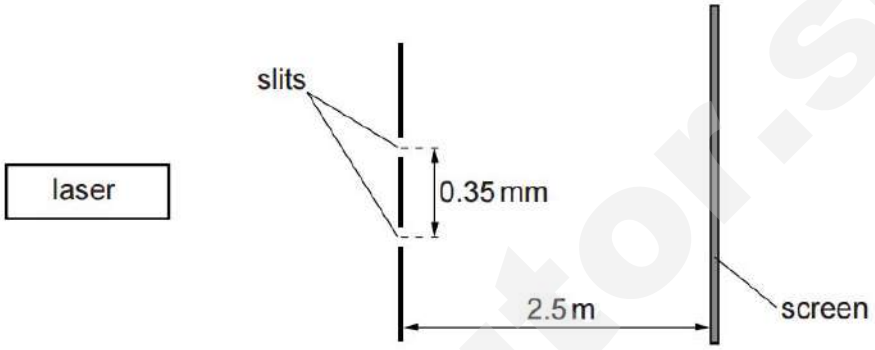

Fig. 5.1 (not to scale)

The laser emits light of wavelength 4.5×10^{-7} m. The distance from the slits to the screen is 2.5 m. The separation of the slits is 0.35 mm. The width of each slit is 2.0×10^{-6} m.

An interference pattern of maxima and minima is observed on the screen.

(i) Explain why an interference pattern is observed on the screen.

…….....

…….....

…….....

…….. [2]

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(ii) One of the slits is now covered with an opaque object.

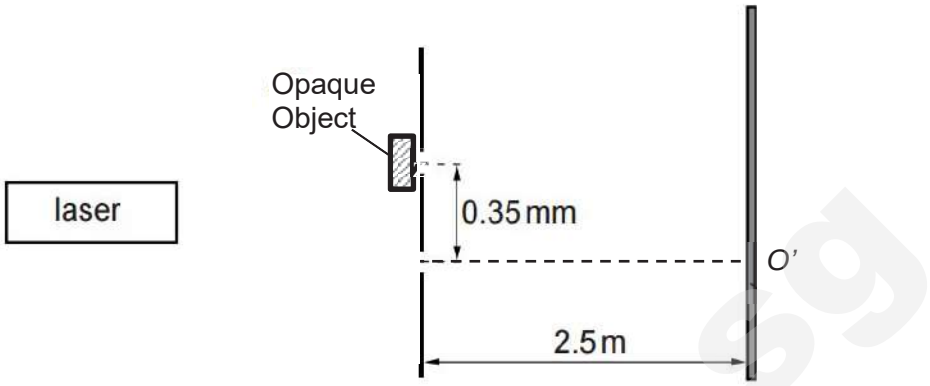

Fig. 5.2

1. On Fig. 5.3, sketch the variation with position of the intensity for the image observed on the screen. Your sketch should show at least 3 maxima. [2]

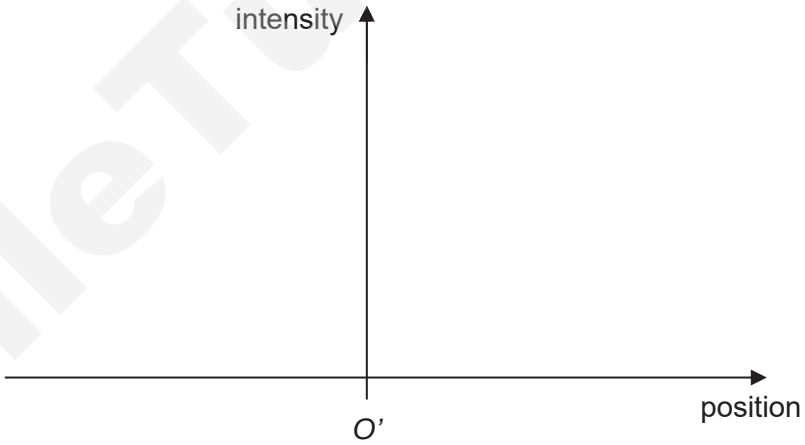

Fig. 5.3

2. Calculate *O'Y*, the distance from *O'* at which the first minima occurs.

O'Y = ... m [2]

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6 Fig. 6.1 shows a set up for the electrolysis of sodium chloride solution using a 12 V cell. When dissolved in water, each sodium chloride yields a pair of oppositely charged ions; a positively charged sodium ion (Na^+) and a negatively charged chloride ion (Cl^-), both with a charge of *e*.

Fig. 6.2 shows the portion of the electrodes immersed in the solution. The electrodes are 7.5 cm apart and the immersed area parallel to each other is 23 cm^2. The resistivity of the given sodium chloride solution is 9.0 Ω cm.

You can assume that Na^+ and Cl^- are the only charge carriers.

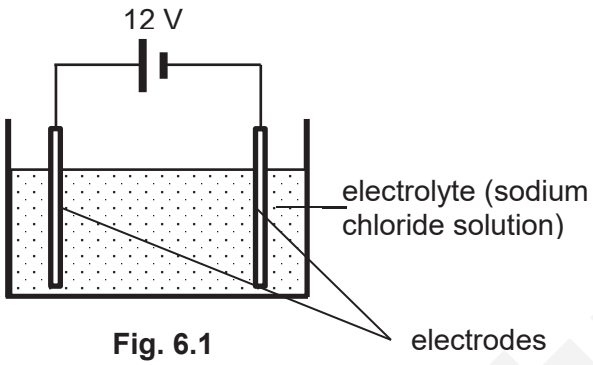

Fig. 6.1

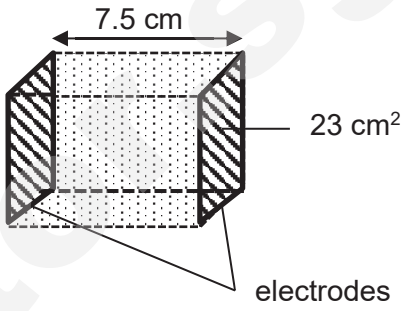

Fig. 6.2

(a) Calculate the current I passing through the sodium chloride solution.

I = ... A [3]

(b) With reference to Fig. 6.1, state the direction of the net motion of sodium and chloride ions.

sodium ion = ...

chloride ion = ... [1]

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(c) To prepare the sodium chloride solution, 1.7 mol of sodium chloride was fully dissolved in 1000 cm^3 of water. Calculate the number density n of the chloride ions.

n = ... cm^{-3} [2]

(d) By assuming that the flow of chloride ions contributes to half the current, calculate the drift velocity v of the chloride ions in the solution.

v = ... cm s^{-1} [2]

(e) Chloride ions forms chlorine gas as the electrolysis process progresses.

State and explain the changes to following.

(i) the current, and

.....

.....

..... [2]

(ii) the drift velocity of the chloride ions.

.....

.....

..... [2]

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7 (a) Fig. 7.1 shows a high voltage supply set up to produce energetic electrons to bombard the cool sodium gas in the discharge tube, giving rise to a line spectrum through a diffraction grating. Fig. 7.2 shows some electron energy levels of a sodium atom.

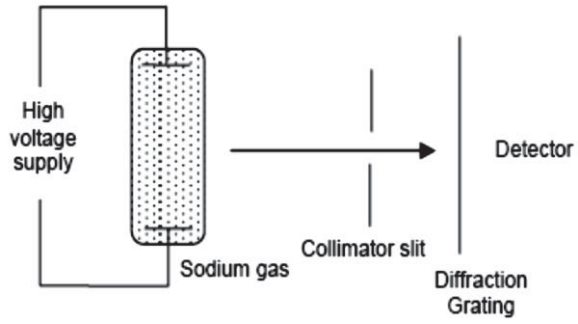

Fig. 7.1

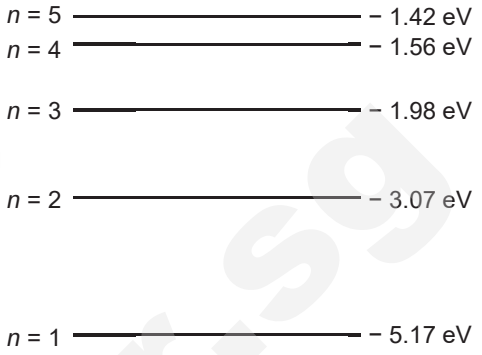

Fig. 7.2

(i) The bombardment of the electrons caused the sodium gas to be excited up to the n = 3 energy level. Sketch the relative positions of the lines on the spectrum observed in Fig. 7.3 below. Label the corresponding transition for each line. [2]

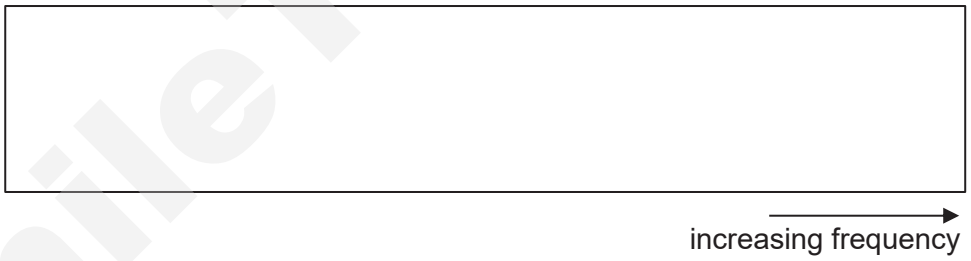

Fig. 7.3

(ii) It is observed that the minimum kinetic energy of the recoil electrons is 0.24 eV. Determine the incident kinetic energy of the electrons that bombard the sodium gas.

incident kinetic energy = …….. eV [2]

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(iii) Another cool gas with energy levels as shown in Fig. 7.4 is now placed between the discharge tube and the collimator slit in the set up in Fig. 7.1.

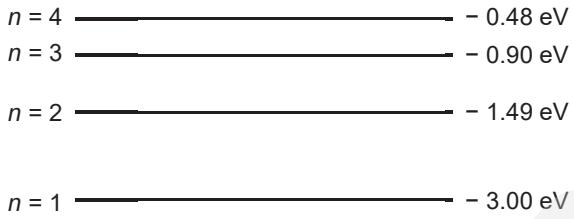

Fig. 7.4

Three faint spectral lines and two bright spectral lines are now detected at the detector. Explain this observation.

.....

.....

.....

.....

.....

..... [3]

(b) In another experiment, an electron beam is accelerated towards a barrier with two slits in it as shown in Fig. 7.5. The two slits has a separation of 272 nm. After passing through the double slit, a pattern was detected using a suitable fluorescent screen placed 240 mm away from the barrier.

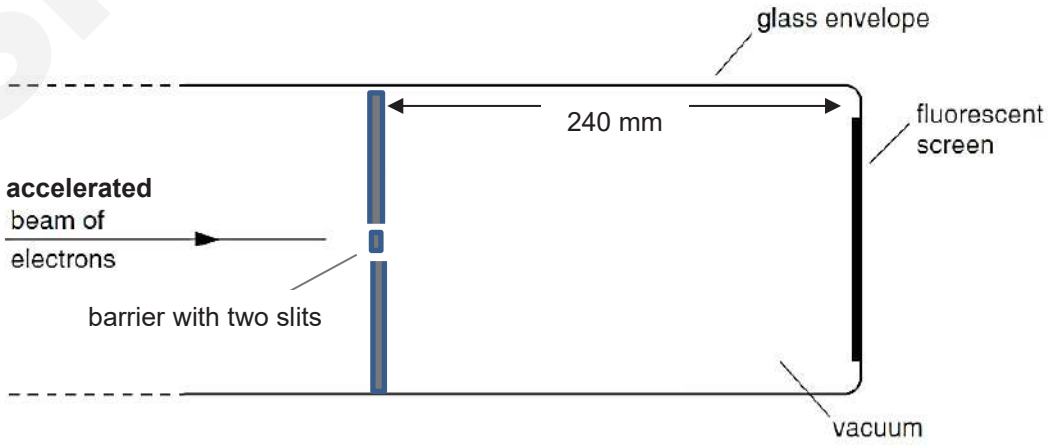

Fig. 7.5

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The resulting pattern (not drawn to scale) observed after several hours is shown in Fig. 7.6.

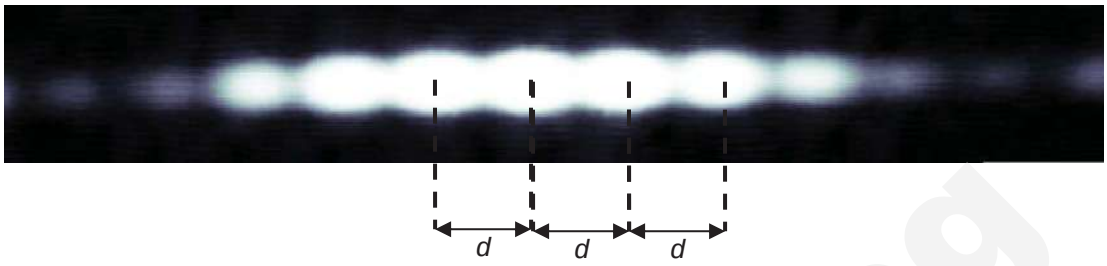

Fig. 7.6

d is the separation between the centres of adjacent bright spots.

(i) Suggest the significance of the observed pattern in Fig. 7.6, on the nature of the electrons.

.....

..... [1]

(ii) If the electrons are initially accelerated across a potential difference of 600 V to reach the two slits in the barrier, calculate *d*, the separation between the centres of adjacent bright spots observed on the screen.

d = ... m [4]

(iii) State and explain a change, if any, which is observed in the pattern on the screen if the electrons are accelerated by a larger potential difference.

.....

..... [2]

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Section B

Answer **one** question in this section in the space provided.

8 **(a)** Define *electric field strength*.

……..

……... [1]

(b) Fig. 8.1 shows two parallel metal plates with a separation of 0.50 cm and the centre of the plates is situated 20 cm from a screen as shown.

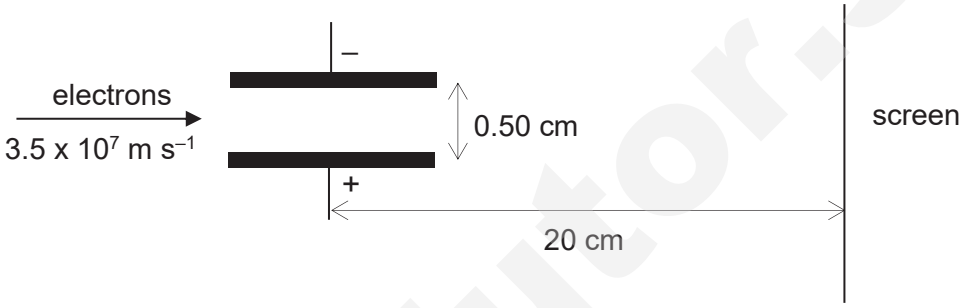

Fig. 8.1

A potential difference of 100 V is applied to the plates such that a uniform electric field is created in the region between the plates. Electrons of speed 3.5×10^7 m s^{-1} enter this region horizontally, mid-way between the plates.

(i) Calculate the acceleration of an electron within the plates.

acceleration = ……. m s^{-2} [2]

(ii) The vertical component of the velocity of an electron at the moment when it exits the plates is 2.3×10^6 m s^{-1}. Determine the time that the electron takes to pass between the plates.

time = …….s [2]

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(iii) A magnetic field is then applied in the region between the plates such that the electrons emerge un-deflected. State and explain the direction of the magnetic field to be applied.

……

……

…… [2]

(iv) The magnetic field is now removed. The potential difference, V, across the plates is now changed and is given by the following equation

$$V = V_o \sin(100\pi t)$$

The r.m.s value of the potential difference is 60 V.

1. Determine the period of the potential difference across the plates.

period = ……s [1]

2. On Fig. 8.2, sketch the variation of potential with time, the trace of the deflected beam of electrons for one period. On the vertical scale, 1.0 cm represents 50 V. On the horizontal axis, 1.0 cm represents 5.0 ms.

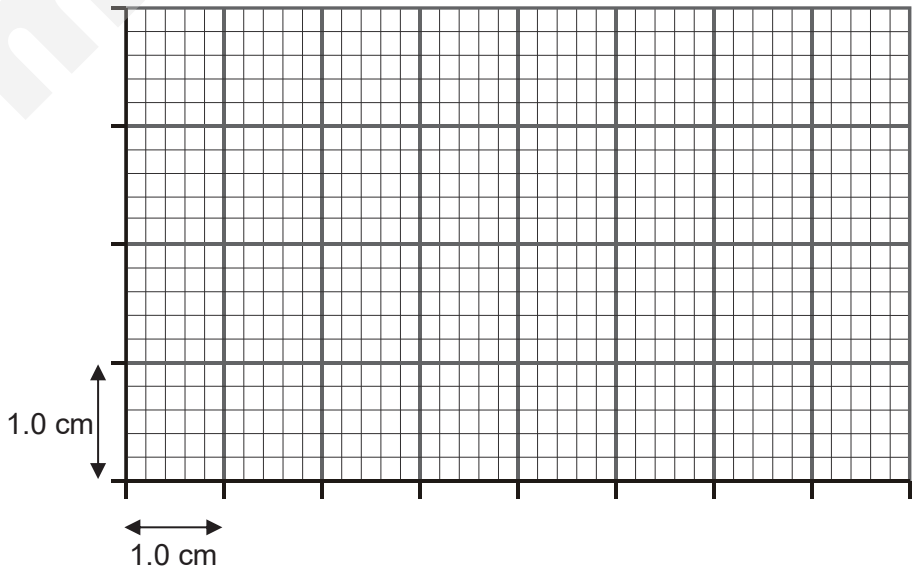

Fig. 8.2

[2]

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8 (c) Two conductors , **A** and **B**, each of length 0.20 m and carrying current of 5.0 A are placed at right angles to the plane of the magnetic field of magnitude 3.2 mT created by a pair of magnets as shown in Fig. 8.3. Conductor **A** carries current out of the plane of the paper while conductor **B** carries current into the plane of the paper.

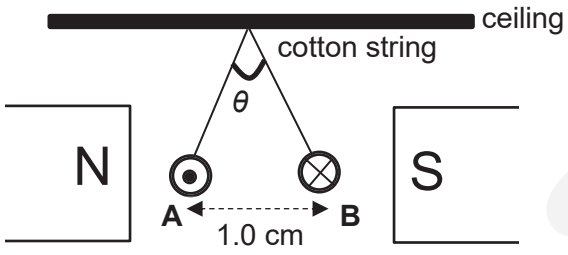

Fig. 8.3

The conductors are hung to the ceiling by cotton strings of equal tensions. At equilibrium, the two conductors make an angle of θ with each other and are separated by 1.0 cm.

You may assume that the entire length of conductors **A** and **B** lie in the magnetic field of the pair of magnets.

(i) Fig 8.4 shows two forces that are acting on conductor **A**. Draw on the same diagram, two other forces that are acting on conductor **A**. Label all forces drawn.

.

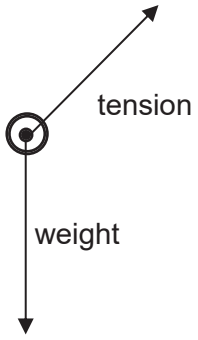

Fig. 8.4 [2]

(ii) Calculate the magnetic force experienced by conductor **A** due to the pair of magnets.

force = ……..N [2]

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(iii) The mass of conductor **A** is 0.35 g. Determine the tension in the cotton string and the angle, θ.

tension = …….. N

θ = ……$^{\circ}$ [4]

(iv) A student claims that since the tension in each of the strings are equal, the conductors have equal masses. State and explain if the claim is valid.

……..

……..

……..

……. [2]

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9 **(a)** The table below shows some of the properties of the ionising radiations alpha, beta and gamma.

Complete the table. [3]

	alpha	beta	gamma
mass		1/1840 *u*	
nature	particle		
penetrating ability		Stopped by few mm of aluminium	

(b) In the early years of the last century, Madame Curie drew an illustration similar to the one in Fig. 9.1 which indicated how the three radiations travelled in air in a uniform magnetic field. Fig. 9.1 is not drawn to scale.

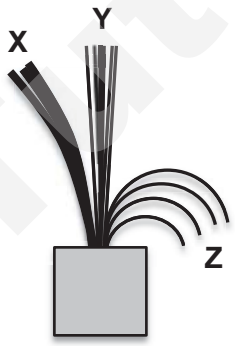

Fig. 9.1

(i) Identify the radiations **X**, **Y** and **Z**.

X: ……..

Y: ……..

Z: …….. [2]

(ii) State what can be deduced from the following observations:

1. The lines for **X** all have approximately the same length.

……

……... [1]

2. The lines for **Z** have different curvatures.

……

……. [1]

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(iii) A student claimed that the nuclear radioactive decay process that produces radiation **Z** produces only two products: a daughter nucleus and radiation **Z**.

Explain, with reference to your answer in **(b)(ii)2.**, why the student's claim is not true.

……

……

……

…… [2]

(c) Define the following terms:

1. *activity*;

…… [1]

2. *half-life*.

…… [1]

(d) The equation below

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + \alpha$$

represents the decay of a uranium nucleus by alpha emission. You may assume that $^{238}_{92}\text{U}$ is initially stationary.

(i) The half-life of $^{238}_{92}\text{U}$ is 1.42×10^{19} s. Determine the mass of $^{238}_{92}\text{U}$ that will give an emission of two α - particles per second.

mass of $^{238}_{92}\text{U}$ = …… g [4]

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(ii) The alpha particle has kinetic energy KE_α of 4.18 MeV. Determine the energy released during one decay process.

energy released = …….. MeV [3]

(e) One common use of radioactivity is to check for cracks in the structure of underground water pipelines.

State two characteristics of a radioactive nuclide that would be ideal for this use.

……..

……. [2]

End of Paper

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics 9749/4

Paper 4 Practical

12 September 2017
2 hours 30 minutes

Class	Reg Number

Candidate Name: _____

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **ALL** the questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

Write your answers in the space provided in the question paper. The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, Question 1&2, Question 3, Question 4 are to be submitted separately.

The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

Examiner's Use	
1	
2	
3	
4	
Total	**/55**

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This booklet consists of 17 printed pages.

1 In this experiment, you will investigate the equilibrium of a wooden rule.

(a) (i) Attach masses to the apparatus as shown in Fig. 1.1.

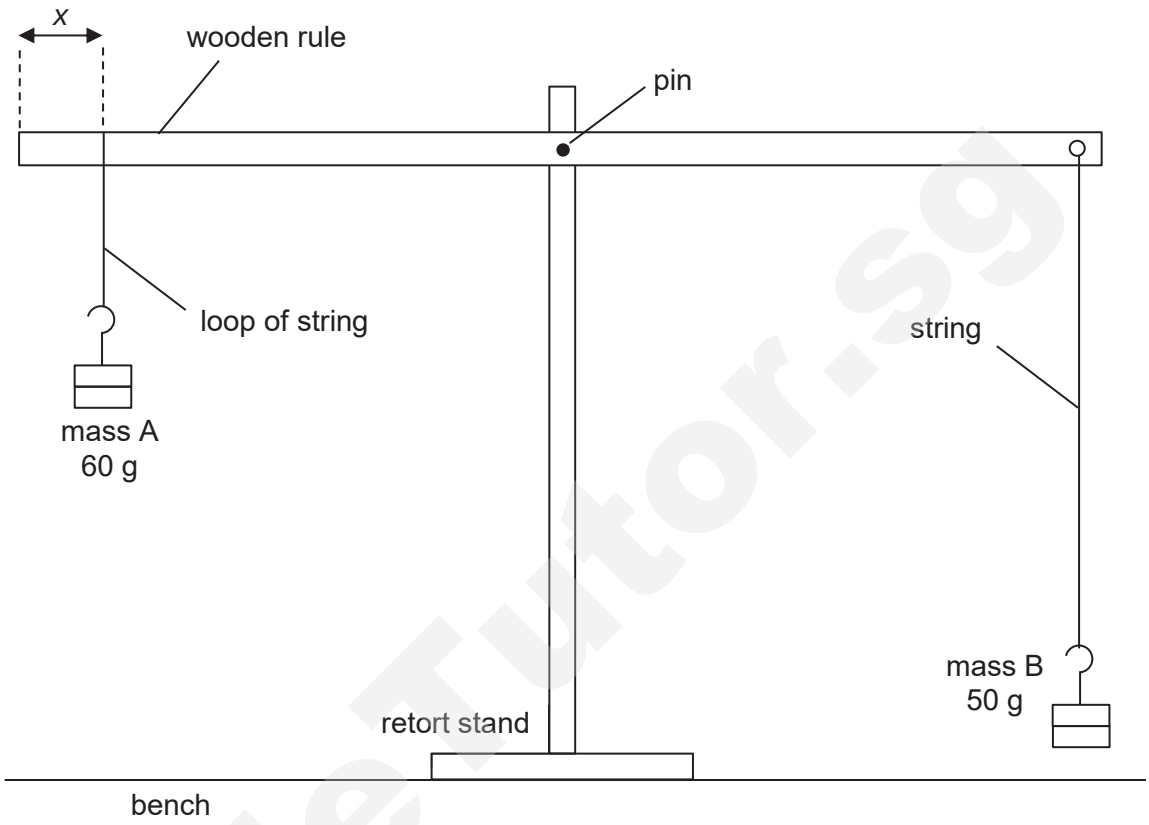

Fig. 1.1

Mass A is suspended from the wooden rule using a loop of string. The distance between the loop of string and the nearest end of the wooden rule is *x*.

(ii) Change *x* until the wooden rule is balanced and approximately parallel to the bench. Measure and record *x*.

x = ... [1]

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(b) **(i)** Remove both masses. Clamp the pulley to the retort stand using two wooden blocks.

Thread the string for mass B over the pulley, and then attach the masses again, as shown in Fig. 1.2.

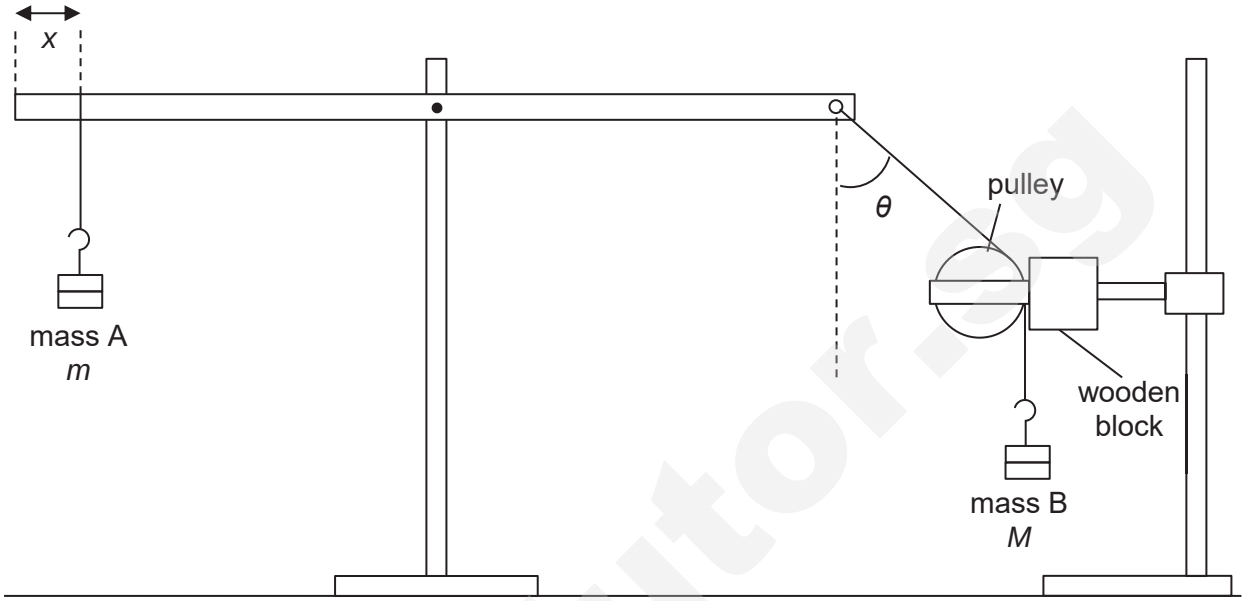

Fig. 1.2

(ii) Transfer 10 g from mass A to mass B.

(iii) With x at the same value as **(a)(ii)**, adjust the position of the pulley until the wooden rule is approximately parallel to the bench.

Measure and record the angle θ that the string for mass B makes with the vertical, as shown in Fig. 1.2.

θ = ... [1]

(iv) Estimate the percentage uncertainty in your value of θ.

percentage uncertainty = ... [1]

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(v) Record the mass m of mass A and mass M of mass B.

m = ...

M = ... [1]

(vi) Calculate the value of $\frac{m}{M}$.

$\frac{m}{M}$ = ... [1]

(c) It is suggested that the cos θ is directly proportional to $\frac{m}{M}$.

Take further measurements to investigate this suggestion and explain whether your results support the suggested relationship.

Present your measurements and calculated results clearly.

.....

.....

.....

.....

..... [4]

[Total: 9 marks]

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2 The resistance of a light-dependent resistor (LDR) changes when it is illuminated with light of different intensities.

In this question, you will investigate how the light detected by a LDR depends on the thickness of an absorber.

(a) **(i)** Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

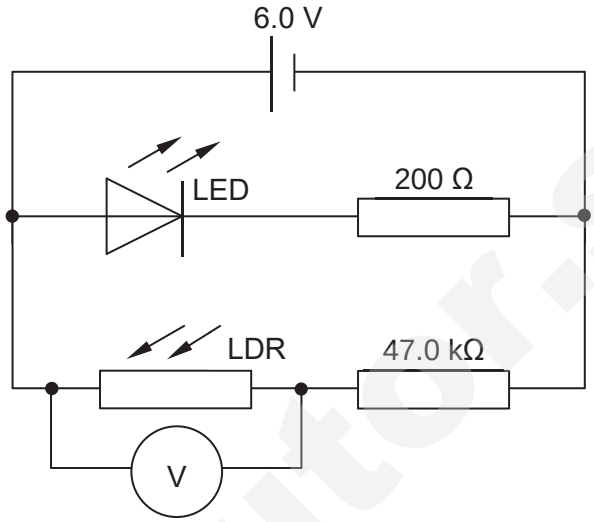

Fig. 2.1

(ii) You are provided with a black straw of approximate length of 4 cm.

(iii) Use the straw and clear adhesive tape to make a cylinder that fits neatly over the LDR and LED.

Cut the cylinder into two halves of approximately 2 cm each and fit the 2 cylinders over the LDR and LED, as shown in Fig. 2.2.

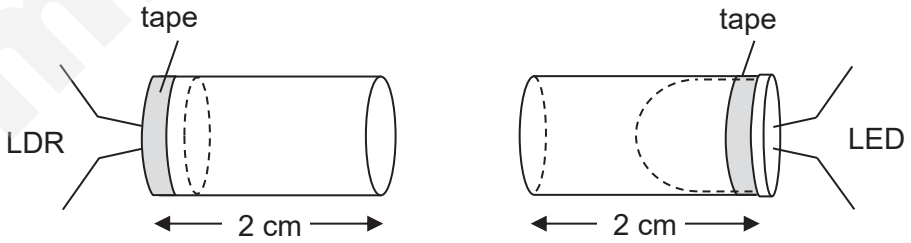

Fig. 2.2

(b) Place the cylinders together, as shown in Fig. 2.3.

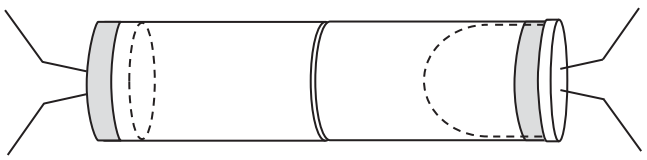

Fig. 2.3

Record the voltmeter reading V_0.

V_0 = ... [2]

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(c) Fold the sheet of tracing paper in half four times so that you have 16 layers.

(i) Measure and record the thickness of these 16 layers.

thickness of 16 layers = ... [1]

(ii) Determine the thickness t of one layer of tracing paper.

t = ... [1]

(iii) Estimate the percentage uncertainty in your value of t.

percentage uncertainty = ... [1]

(d) **(i)** Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4.

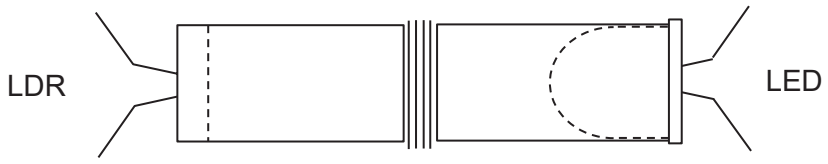

Fig. 2.4

Record the voltmeter reading V.

V = ... [1]

(ii) Repeat **(d)(i)** using eight layers of tracing paper.

V = ... [1]

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(e) **(i)** State and explain two significant sources of error or limitations of the procedures for this experiment.

1. .....

.....

2. .....

..... [2]

(ii) Suggest two improvements that could be made to the experiment and explain how this addresses the errors identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure.

1. .....

.....

2. .....

..... [2]

(f) Suggest changes that could be made to the experiment to investigate how the light detected by a LDR depends on the angle between the polarising axes of a pair of polarizing filters.

You may assume that a pair of *unmarked* polarizing filters is available.

You may draw a diagram to show how the apparatus would be arranged.

.....

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.....

.....

..... [3]

[Total: 14 marks]

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Turn over for Question 3

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Candidate Name: _____ ( ) Class: _____

3 In this experiment you will investigate the relationship between the current in a copper wire and the orientation of a magnet suspended near to the copper wire. The magnet (with a pointer attached) has been suspended as shown in Fig. 3.1.

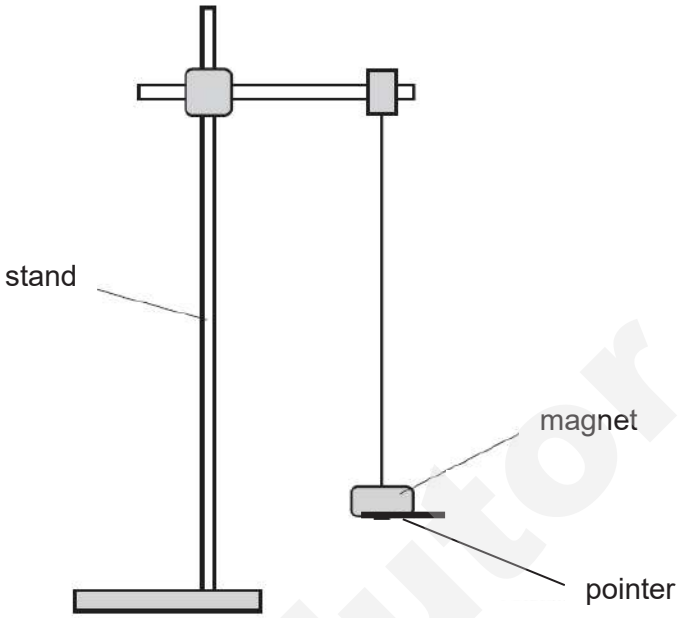

Fig. 3.1

A piece of straight copper wire has been taped to one edge of a 50 cm rule and a protractor attached to the centre of the rule. You should not disturb the copper wire or the protractor from their positions on the rule during the course of the experiment.

(a) (i) Set up the circuit shown in Fig. 3.2.

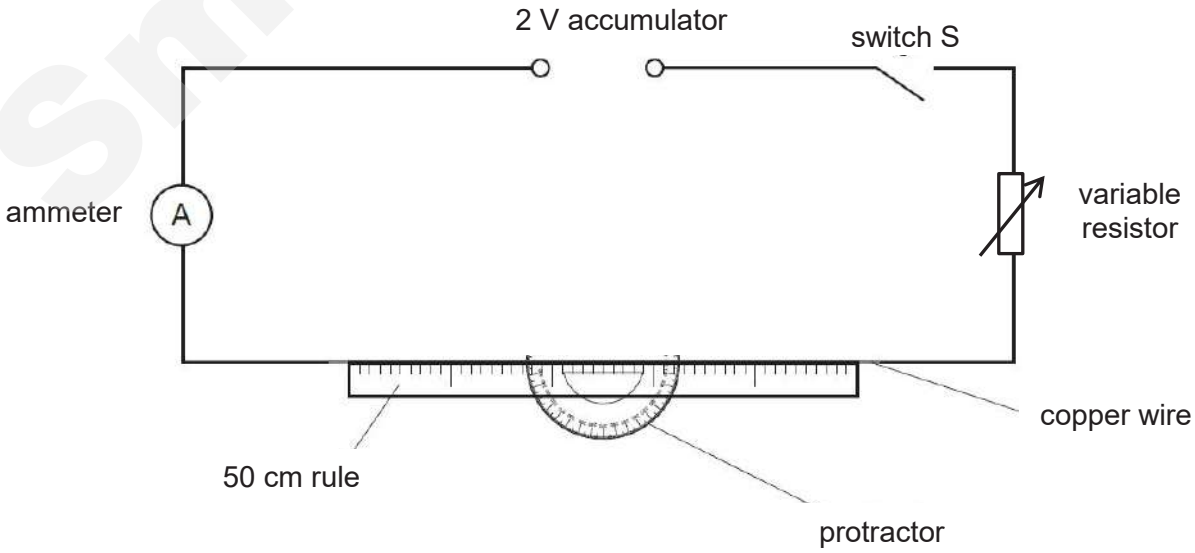

Fig. 3.2

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(ii) Place the rule just below the magnet such that the pointer is at most 5 mm above the top of protractor. The pointer should be perpendicular to the wire and the centre of the protractor directly below the point of suspension. The arrangement is shown in Fig. 3.3.

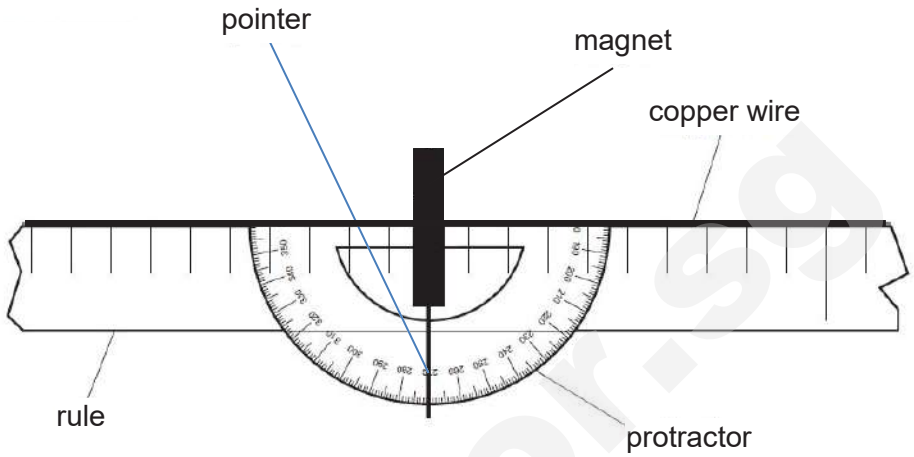

Fig. 3.3 (top view)

(iii) Close switch S.

(iv) Adjust the current until the pointer shows a measurable deflection. Slow down the motion of the magnet by touching it. When the pointer is steady, measure and record the angle of deflection θ and the current I.

θ = ...

I = ... [1]

(v) Estimate the percentage uncertainty of θ.

percentage uncertainty of θ = ... [1]

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(vi) Vary the resistance of the variable resistor and repeat **(iv)** to obtain further sets of readings for θ and I. The current should not exceed about 4 A.

[7]

(vii) Open switch S.

(b) The formula which relates θ and I is

$$\tan\theta = A I + B$$

where A and B are constants.

Plot a graph to determine the values of A and B.

A = ...

B = ... [4]

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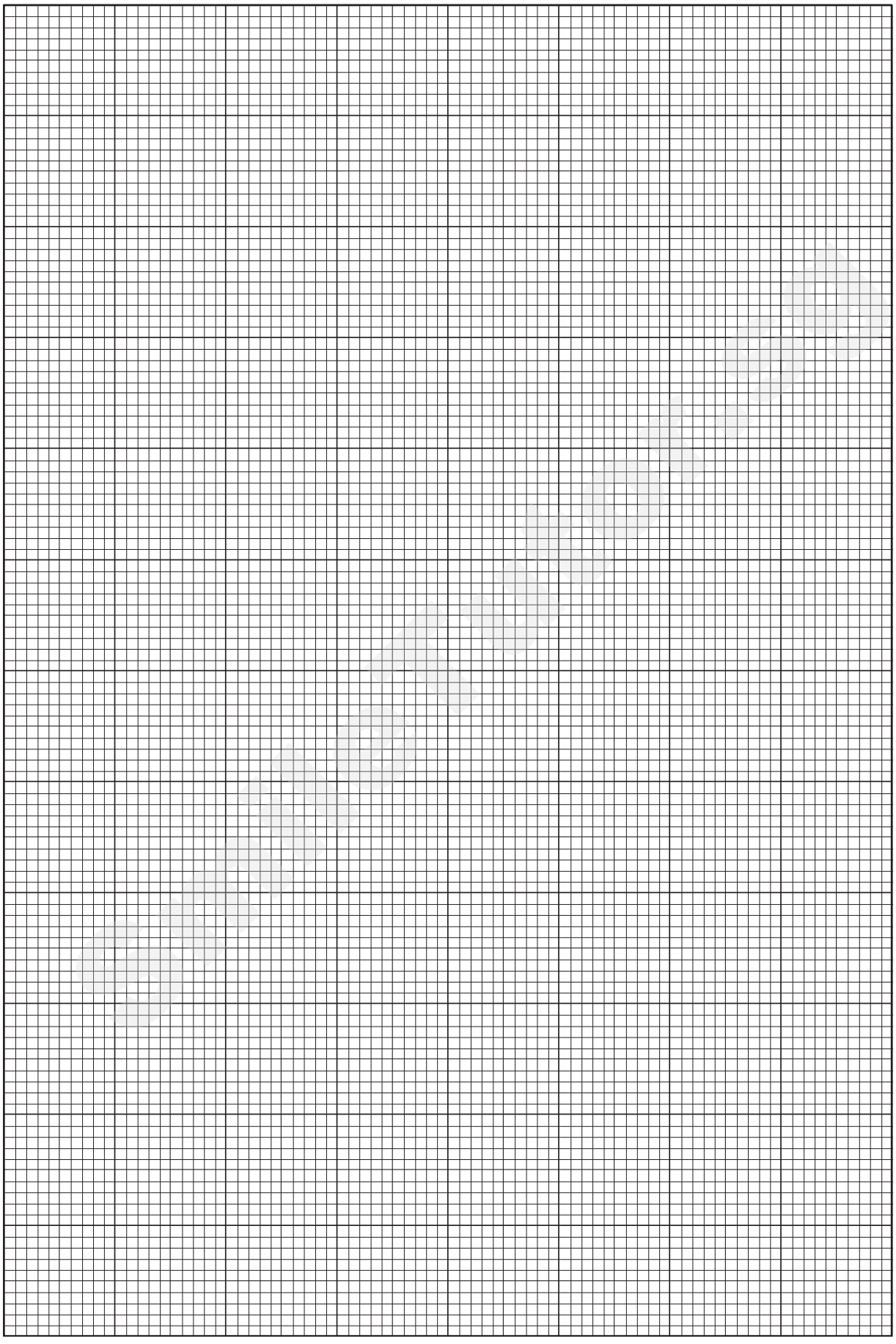

[3]

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(c) Comment on any anomalous data or results that you may have obtained. Explain your answer.

.....

..... [1]

(d) **(i)** Use the results from your experiment to calculate a value for θ when the current in the copper wire is 15 A.

θ = ... [1]

(ii) Give one reason why it may be difficult to verify this experimentally.

.....

..... [1]

(e) It is known that constant A is affected by the magnetic flux density due to the wire. On the graph grid on page 12, sketch a second graph to represent the results if distance between the magnet and the wire is increased. Label this graph **Z**. [1]

[Total: 20 marks]

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Turn over for Question 4

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4 Each of the propellers on a drone consists of two or more blades connected to a motor shaft. As the motor rotates air is drawn through the blades. This results in a thrust on the propeller, hence lifting the drone. Fig. 4.1 shows a propeller used in a drone. The speed of rotation of the motor is determined by the power supply it is connected to.

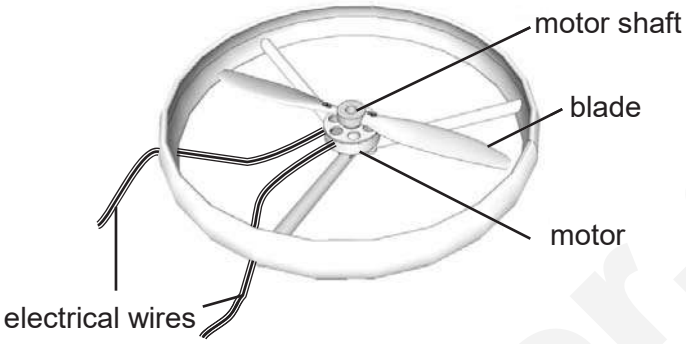

Fig. 4.1

A student suggests that the average thrust T on the propeller depends on the rotational speed ω of the blade, the blade angle θ, and the density of air.

The relation between the average thrust T, ω, and θ may be written in the form

$$T = k\omega^a \sin^b \theta$$

where k, a, b are constants.

You are provided with the following apparatus.

- a number of propellers with different blade angles indicated,
- tachometer (an instrument that measures the rotational speed of a shaft)
- electronic balance

You may also use any of the other equipment usually found in a physics laboratory.

Design an experiment to determine the values of k, a, b.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account, you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedures to be followed,

(d) how the values of k, a and b are determined from your readings,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[Total: 12 marks]

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Diagram

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End of Paper

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2017 H2 P1 Preliminary Examination

1 Ans: D

A: Typical bus mass = 3000 kg, speed = 60 km/h ≈ 17 m s^{-1}, so KE ≈ 400 000 J
B: Typical power of domestic light = 10 to 90 W
C: 300 K is 27 °C, too low for hot oven
D: Typical tyre is 60 cm radius, 20 cm width, 4 cm breadth ⇒ volume ≈ 0.03 m^3

2 Ans: B

$s_{car} = 0 + 0.5(2)t^2$

$s_{truck} = (14)t$

$s_{car} = s_{truck}$

$t = 14$ s

3 Ans: A

To create rotational equilibrium, the sum of moments exerted by the weight of each material about the knife-edge must be equal. Another way is to use visual inspection to estimate the location of the centre of gravity (CG) for the composite rod. The knife-edge must be below the CG for rotational equilibrium.

For C and D, the CG lies in the middle of the rod so knife-edge is placed correctly below the CG.

For B, the CG is off-centre to the right as material B is concentrated to the right. The knife-edge is also positioned more to the right (from centre) There is a chance that rotational equilibrium can be established.

For A, the CG is also off-centre to the right since material B is concentrated to the right, but the knife-edge is at the centre. Hence, rotational equilibrium cannot be established.

4 Ans: A

Since the floor is frictionless, contact force at point B is only the normal contact force.

At equilibrium,

At point A, there is an upward vertical force (magnitude of 390-317=73 N) to ensure net vertical forces is zero.

At point A, there is a leftward force to counter the rightward tension force.

Hence, reaction force at A is pointing as shown in diagram A.

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5 **Ans: A**

Change in momentum = area under F-t graph

Area under F-t graph from 0 to 10 seconds = 0.5 x (8+4) x 12 + [(-0.5) x (2) x (12)] = 60 N s

Change in momentum = final momentum – initial momentum

$60 = mv - 0$

$v = 200 \text{ m s}^{-1}$

6 **Ans: D**

Using relative speed of approach = relative speed of separation

$u_1 - u_2 = v_2 - v_1$

$0.100c - (-0.040c) = v_2 - v_1$

$v_2 = 0.140c + v_1$ ---------(1)

Using conservation of momentum

$1u \times 0.100c - 4u \times 0.040c = 1u \times v_1 + 4u \times v_2$

$0.100c - 0.160c = v_1 + 4v_2$ ---------- (2)

Substitute eqn (1) into (2)

$-0.060c = v_1 + 4 \times (0.140c + v_1)$

$v_1 = -0.124c$

$v_2 = +0.016c$

7 **Ans: D**

The constant force pulling the object down the slope, $F = mg\sin\theta$

Instantaneous power, $P = Fv = mg\sin\theta\, v$

Loss in GPE = gain in KE

$mgh = \frac{1}{2} m(v^2 - 0^2)$

$v = \sqrt{2gh}$

$\therefore P = mg\sin\theta\sqrt{2gh}$

8 **Ans: A**

EPE is equal to the area under the force-extension graph. In this case, a stretched length vs force graph is plotted, hence we consider the area that **Q** makes with the vertical axis.

Note that at point Q, the spring has undergone plastic deformation, hence some energy has been released as heat (represented by area Y).

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9 Ans: C

Angular velocity of accurate clock = $\frac{2\pi}{60\times 60} = 1.745329\times 10^{-3}$ rad s^{-1}

Javier watch behind by

$(1.745329 - 1.744)\times 10^{-3}\times 24\times 3600 = 0.114847372$ rad

$\frac{0.114847372}{1.745329\times 10^{-3}} = 66$ s

10 Ans: D

For the man (where *m* is the mass of the man),

$$g - \frac{N}{m} = r\omega^2$$

For the spacecraft, (where *M* is the mass of the man),

$$g + \frac{N}{M} = r\omega^2$$

Since both the man and the spacecraft are at the same distance away from the planet and orbits the planet with the same angular velocity, hence *N* (normal contact force between the man and the spacecraft) is zero. The man is floating in the spacecraft.

OR

Consider both the man and the spacecraft as a system with total mass M_T,

$$M_T g = M_T r\omega^2$$

$$g = r\omega^2$$

For the man, (where

$$g - \frac{N}{m} = r\omega^2 = g$$

$$\therefore \frac{N}{m} = 0$$

11 Ans: C

For Satellite A, gravitational force provides for centripetal force, (*M* is the mass of the planet, m_A is the mass of Satellite A and *r* is the distance between Satellite A and the planet)

$$\frac{GMm_A}{r^2} = m_A\frac{v^2}{r}$$

Kinetic energy, E_k = ½ $m_A v^2$

$\frac{1}{2}m_A v^2 = \frac{GMm_A}{2r} = \frac{GMm_A}{2(2R)}$ (Since Satellite A is 2*R* away from the centre of the planet)

For satellite B, (*M* is the mass of the planet, m_B is the mass of Satellite B and *r* is the distance between Satellite B and the planet)

$\frac{1}{2}m_B v^2 = \frac{GMm_B}{2r} = \frac{GM2m_A}{2(3R)} = \frac{4}{3}E_k$

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12 **Ans: C**
reasoning:

$$\text{Total Energy} = \frac{1}{2}m\omega^2 x_0^2$$

$$5 = \frac{1}{2}(0.4)(\frac{2\pi}{T})^2(0.25)^2$$

$$T = 0.31s$$

13 **Ans: D**
reasoning:

Increased damping, it will take longer to complete an oscillation. Hence period increases and natural frequency at resonance decreases.

14 **Ans: B**
reasoning:

For a closed pipe, the fundamental frequency occurs at 0.25λ
Length of pipe = 2 m = 0.25 λ,
Hence,
f = v/λ = 320 / 20 = 40 Hz

15 **Ans: D**
reasoning:

Wave	Approx Size	Obstacle	Obstacle Size	Conclusion
microwaves	0.1 cm – 10 cm	Steel post	10^{-1} m	Most similar in order of magnitude
radiowaves	1 m – 10 m	Copper wire	10^{-3} m	
sound waves	1.7 cm – 17 m	Human hair	10^{-5} m	
visible light wave	400-700nm	Opening of classroom	2 m	

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16 **Ans: C**
reasoning:

Path difference is 10 cm
For point Z to be at destructive interference, it needs to be in multiples of (n+1/2) λ

Trial and error for all 4 options

If λ = 2cm, PD = 5 λ (CI)
If λ = 3cm, PD = 3.33 λ (no complete cancellation)
If λ = 4cm, PD = 2.5 λ (DI)
If λ = 26cm, PD = 1.67 λ (no complete cancellation)

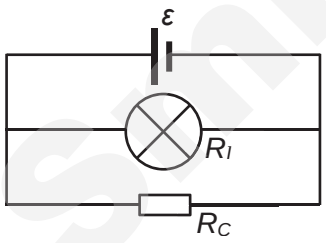
17 **Ans: C**
A is incorrect.There is no work done for path **W** as the change in potential is zero.
B is incorrect. Positive work (path **X**) is done when the positive particle is brought to a point of lower potential while negative work (path **Y**) is done when the positive particle is brought to a point of higher potential.
C is correct. Positive work is done by the electric field when the positively charged particle is brought from a position of higher potential to a position of lower potential (path **Z**) and the change in potential is the largest.
D is incorrect. Work done is zero for path **W** as the change in potential is zero.

18 **Ans: B**

$$\tau = qE \times d = (2 \times 1.6 \times 10^{-19})(\frac{2.0 \times 10^{2}}{0.001})(4.0 \times 10^{-12} \sin 30^{0})$$

$$= 1.3 \times 10^{-25} \text{Nm}$$

19 **Ans: A**



The same potential difference across both the lamp and the resistor.

$$P_{lamp} = \frac{\varepsilon^2}{R_l} \qquad P_{resistor} = \frac{\varepsilon^2}{R_C}$$

Fraction of power delivered to lamp

$$= \frac{P_{out}}{P_{in}} = \frac{\frac{\varepsilon^2}{R_l}}{\frac{\varepsilon^2}{R_l} + \frac{\varepsilon^2}{R_C}} = \frac{R_C}{R_l + R_C}$$

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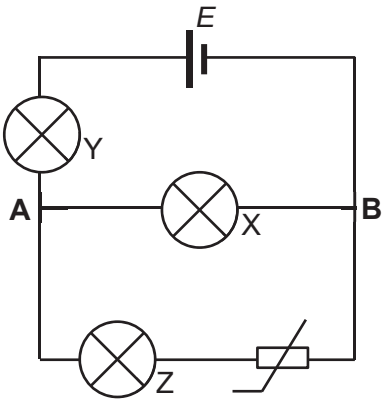
20 Ans: C

When heated up, resistance of an NTC thermistor decreases.



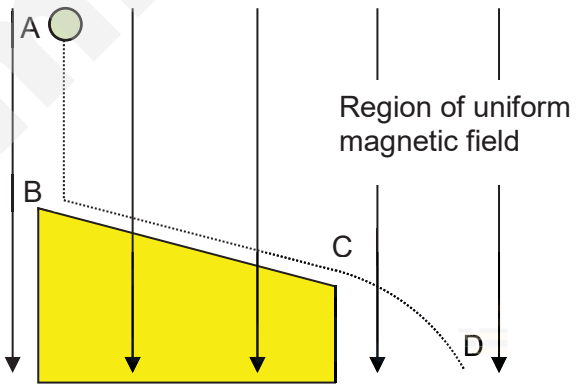
Effective resistance across points **AB** decreases. Hence V_{AB} decreases and p.d. across Y increases. Y will become brighter and X dims.

21 Ans: A

Electric force on the electrons is downwards. Hence magnetic force on electrons is upwards. Using Fleming's LHR, the magnetic field is pointing out of the paper.

$$F_E = F_B$$
$$qE = Bqv$$
$$B = \frac{E}{v} = \frac{20 / 0.005}{v} = \frac{4000}{v}$$

22 Ans: B



$E = Blv$, where v is the horizontal component of the rod's velocity. From Point A to B, the rod is moving vertically and E is zero. From B to C, as the rod rolls down the slope, the component of its weight parallel to the slope caused its velocity to increase. Hence, Its horizontal velocity increases at a constant rate and E increases linearly. From C to D, the rod is moving in projectile motion. Its horizontal velocity is constant and E remains constant.

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23 **Ans: A**

The forces acting on XY and ZW have the same magnitude in opposite directions.
These two forces form a couple with a torque as follow:
$\tau = NBIL \times d = (20)(0.80)(I)(0.17) \times (0.11) = 1.35$
I = 4.5 A

24 **Ans: B**
reasoning:

r.m.s potential difference in secondary coil $= 8.0 \times 2.5 = 20$ V

r.m.s potential difference in primary coil $= 20 \div 4 = 5.0$ V

(This is a step-up transformer with a 1:4 turn ratio).

25 **Ans: B**
reasoning:
From $pV = nRT$
$n_1 RT_1 = n_2 RT_2$
$\frac{m_1}{M_R} RT_1 = \frac{m_2}{M_R} RT_2$
$m_2 = \frac{(273.15 + 10)(15)}{(273.15 + 30)} = 14.0$ kg

26 **Ans: C**
reasoning:
A is incorrect as this is only true if the system is an ideal gas system.
B is incorrect as during change of state, internal energy can increase but temperature will remain the same.
D is incorrect as it is possible for a system with lower temperature to have the same amount of internal energy as another system if the system with lower temperature have much more particles.

C is correct as internal energy of a system can be increased by simply doing work on the system while keeping the heat transfer process zero.

27 **Ans: B**

B has the lowest wavelength/ highest frequency as it has the largest stopping potential. Stopping potential is a measure of the maximum KE of the photoelectrons which is dependent on the frequency of the radiation.

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28 **Ans: D**

$$\Delta x\,\Delta p \geq h \quad , \quad \Delta p = m\Delta v$$

$$\therefore \Delta v = \frac{h}{\Delta x\,.m} = \frac{6.63\times10^{-34}}{}\left(\frac{1}{50\times10^{-9}\times9.1\times10^{-31}}\right)$$

$$\Delta v = 1.5\times10^{4}\ m s^{-1}$$

29 **Ans: D**

reasoning:
To form back the same isotope, mass number need not be the same but atomic number must be the same.

Ejecting an alpha particle causes the mass number and atomic number to decrease by 4 and 2 respectively.

Releasing two beta particles will cause no change in the mass number but atomic number will increase by 2, hence return back to the original atomic number.

30 **Ans: C**

reasoning:
Let *C* be original number of counts due to the α-source.

Let *B* be the background count.
C + *B* = 300 (1)
0.5*C* + *B* = 155 (2)
Solving, *C* = 290
Lead would block all the counts due to the α-source.
Hence, only background count of 10 is detected.

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H2 P2 Prelim Solutions

1 (a) In a uniform circular motion, although the linear speed remains unchanged, its direction changes with time [B1], hence the velocity is always changing. So the motion is accelerated. By Newton's second law, a resultant force [B1] must be acting on it. Since the change in velocity is directed towards the centre of the circle [B1], the acceleration, and hence the resultant force is directed towards the centre of the circle. [3]

(b) (i) T = Mg = 0.90 x 9.81 = 9.829 N

Resultant force

$$=\sqrt{T^2-(mg)^2}$$

$$=\sqrt{(8.829)^2-(0.30\times 9.81)^2}$$ [1]

$$=8.32 \text{ N}$$ [1]

(ii) Resultant force = $mr\omega^2$

$$9.76 = mr(2\pi f)^2$$ [1]

$$r=\frac{8.324}{0.30\left(2\pi\left(\frac{175}{60}\right)\right)^2}=0.0826\ m$$ [1]

(iii) It would not be possible [A1] for the string to be horizontal because the string needs to make an angle with the horizontal such that there is a vertical component of the tension to balance the weight [M1]. [2]

2 (a) (i) The **gravitational potential, ϕ,** at a point in a gravitational field created by a mass *M*, is the work done per unit mass, by an external force in bringing a small test mass from infinity to that point without a change in kinetic energy. [B2]

(b) (i) Gravitational force provides for centripetal force [B1]

$$F_g=\frac{M_E v^2}{R}$$

$$\frac{GM_S M_E}{R^2}=\frac{M_E v^2}{R}$$

$$E_k=\frac{1}{2}M_E v^2=\frac{GM_S M_E}{2R}$$ [B1]

$$E_p=\frac{-GM_E M_S}{R}$$ [B1]

$$E_T=E_p+E_k$$

$$E_T=\frac{-GM_E M_S}{R}+\frac{GM_E M_S}{2R}=\frac{-GM_E M_S}{2R}$$ [B1]

(ii) Since total energy at infinity is zero, when total energy is negative, it implies that the system is bounded / the Earth is being attracted to the Sun / work needs to be done in order to move the Earth out of the gravitational field of the Sun. [B1] [B1]

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(c) Due to the presence of the Earth, the resultant gravitational force experienced by the satellite is less than the gravitational force the Sun exerts on it. [B1]
Hence as g field strength experienced by satellite is weakened, it results in a smaller orbital radius for the same period. [B1]

3 **(a)** Defining equation is $a = -\omega^2 x$. [B1]

Where a is the acceleration of the system
ω is the angular frequency / angular velocity of system
x is the displacement of the system from the equilibrium [B1]

(b) **(i)**



$F_1 = k(e + x)$ [M1]
$F_2 = k(e - x)$

Resultant force
$= F_1 - F_2$
$= k(e + x) - k(e - x)$ [M1]
$= 2kx$ [A0]

(ii) Explanation of negative sign (any one of the following)
- Since net force and displacement are in opposite direction
- Since displacement is to the right and restoring force is to the left [M1]

By Newton's 2nd Law, $F_{net} = ma$ [M0]

$-2kx = ma$

Hence, $a = -\dfrac{2kx}{m}$ [A1]

(iii)

$$\frac{2kx}{m} = \omega^2 x$$

$$\frac{2k}{m} = (2\pi f)^2$$

$$\frac{2(80)}{1.500} = (2\pi f)^2$$ [M1]

$$f = 1.6Hz$$ [A1]

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4 (a) (i) Faraday's Law of Electromagnetic Induction states that the induced e.m.f ε is **directly proportional** to the **rate of change of magnetic flux linkage Φ** or the **rate of cutting of magnetic flux**. [B1]

Lenz's law states that the **induced e.m.f. will be directed such that the current which it (e.m.f.) causes to flow opposes the changes that is producing it** (e.m.f.). [B1]

(ii) Alternating current in the solenoid produces an alternating magnetic flux density. [B1]

This causes a changing magnetic flux linkage in the coil, and by Faraday's law the rate of change of magnetic flux linkage through the coil induces an e.m.f [B1]

(iii) $B = \mu_o nI$

$= 4\pi \times 10^{-7}(400/0.50)(1.5)$

[C1] Correctly substituting values for $B = \mu_o nI$ or $\varepsilon = NA\dfrac{dB}{dt}$

Induced e.m.f =

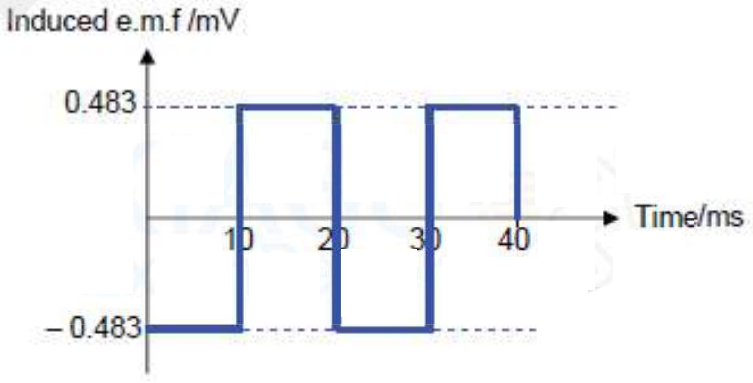
$$\frac{dNBA}{dt}$$

$$= NA\frac{dB}{dt}$$

$$= (8)(0.01\times 0.02)\frac{4\pi\times 10^{-7}\left(400/0.50\right)\left(1.5-(-1.5)\right)}{10\times 10^{-3}}$$ [M1]

$= 4.83 \times 10^{-4}$ V [A1]

(iv)



[B2] – correct profile with correct labels
OR
[B1] – correct profile but wrong/missing labels

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(v)

$$\text{Max Power} = \frac{(4.83x10^{-4})^2}{2.0} \quad \text{[M1]}$$

$$= 1.17 \times 10^{-7}\,\text{W}$$

[A1]

(vi) Any one below: [B1]
Increase the current in the solenoid
Increase number of turns per unit length of the solenoid
Increase the frequency of the A.C. current through solenoid
Increase the number of turns in the rectangular wire
Increase cross sectional area of rectangular wire
Adding an iron core inside rectangular coil

5 (a) By transmitting electrical power in a.c. mode, the transmission voltage can be stepped up. [B1]

This will reduce power loss in the cables due to a smaller transmission current. [B1]

(b) (i)

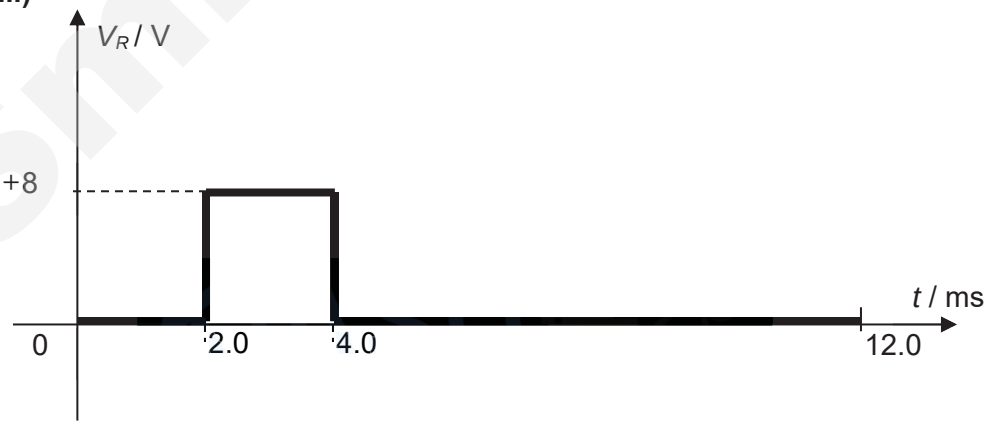
$$V_{rms} = \sqrt{\frac{2(10.0)^2(2.0) + (20.0)^2(2.0) + 2(10.0)^2(2.0) + (20.0)^2(2.0)}{12.0}} \quad \text{[M1]}$$

$$= 14\ \text{V} \quad \text{[A1]}$$

(ii) 1. 0 V [A1]

(ii) 2. p.d. across resistor R = 20 – 12 [M1]
=8.0 V [A1]

(iii)



1 mark for shape of graph.
1 mark for labelled axes (if graph is correct)

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6 (a) (i) using Ideal Gas Equation $PV = nRT$, at constant P,

$$T = \frac{V_T}{V_{Ttr}} \times Ttr$$ [M1]

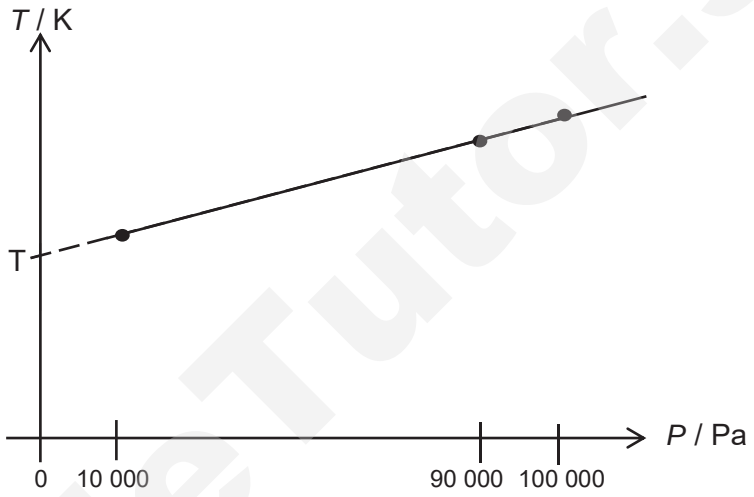
Ttr = 273.16 K [M1]

$$T = \frac{(100000)(503.30)}{(100000)(398.53)} \times Ttr$$

$= 344.97$ K (5 s.f.) [A1]

(ii) The gas in the pressure gas thermometer is <u>not ideal</u>. [A1]

(iii)



Plotting straight line graph and extrapolating to vertical axis (not origin) – [B1]

Labelling T correctly – [B1]

Real gas approaches ideal gas behavior at low pressures. [B1]

(b) (i) During evaporation, the <u>more energetic water molecules have sufficient energy to escape</u> from the body surface. [B1]

Hence, the <u>average energy of the molecules left behind will be lower</u> and <u>temperature falls</u>. [B1]

(ii) Power removed by sweating
$= 0.85 \times 350 = 297.5$ W [M1]

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$$P = \frac{Ml}{t} = \frac{\rho V l}{t} \qquad \text{[M1]}$$

$$\frac{V}{t} = \frac{P}{\rho l}$$

$$= \frac{297.5}{(1000)\left(2.41\times10^{6}\right)}$$

$$= 1.2344\times10^{-7}\,\text{m}^3\ \text{s}^{-1}$$

$$= 4.44\times10^{-4}\ \text{m}^3\ \text{hr}^{-1} \quad \text{[A1]}$$

7 a (i) 78, 78 [B1]

(ii) [B1] for plotting correctly within ½ smallest division.
[B1] for sketching good fit curve



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(iii) -20.5 ± 1.0 mm

(iv) $\frac{Q_s}{\text{Actual load}} = \frac{58+68}{2} = 63\%$ [B1]

Assumption: There is a linear relationship of Qs to actual load between 50 tons and 60 tons of actual load. [B1]

(v) Elastic settlement meant the settlement of the pile/ distance or length that pile sinks into ground that follows elasticity theory. [B1]

(vi) By Newton's third law, when the force by hydraulic jack acted on the loading platform is equal to the force by the loading platform acted on the hydraulic jack but in different direction. In this way, the pile is being load tested accordingly.
[B1] – correctly relating the acted forces
[B1]- correctly relating N3L

(vii) Upthrust $= V\rho g$

$$= \pi \frac{d^2}{4} l \rho g$$

$$= \pi \frac{0.8^2}{4} \times 10.0 \times 1050 \times 9.81 \text{ [M1]}$$

$$= 51.8 \text{ kN [A1]}$$

(viii) A large factor of safety is needed as the soil condition underground can be erratic. [B1]

(b) **(i)** Energy input = Force x distance moved
= 600 x 9.81 x 0.3 [M1]
= 1770 J [A1]

(ii) $\text{time} = \frac{2L}{v} = \frac{2 \times 30.5}{4000} = 0.0153$ s [A1]

(iii) [B1] Possible reason:
There is a crack in the pile (such that the wave gets reflected before the tip of the pile).

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(iv) $E = \dfrac{\rho c^2}{k} = \dfrac{23.5 \times 1000 \times 4000^2}{9.81} = 38.3 \times 10^9$ Pa

$$\frac{\Delta E}{E} = \frac{\Delta \rho}{\rho} + 2\frac{\Delta c}{c}$$
$$= \frac{0.4}{23.5} + 2 \times \frac{400}{4000}$$
$$= 0.217 \quad \text{[M1]}$$
$$\Delta E = 0.217 \times 38.3 \times 10^9$$
$$= 8 \times 10^9 \text{ Pa (1 s.f.)} \quad \text{[M1]}$$

Therefore, $E \pm \Delta E = (38 \pm 8) \times 10^9$ Pa

$= (38 \pm 8) \times 10^6$ kPa [A1]

[A1] for correct units; kN m^{-2} or N m^{-2} or kPa or Pa (with correct values)

OR

$$E_{\max} = \frac{\rho c^2}{k} = \frac{23.9 \times 1000 \times 4400^2}{9.81} = 47.2 \times 10^9 \text{ Pa}$$
$$E_{\min} = \frac{\rho c^2}{k} = \frac{23.1 \times 1000 \times 3600^2}{9.81} = 30.5 \times 10^9 \text{ Pa}$$ [M1--- for identifying max and min]

$$E_{average} = \frac{E_{\max} + E_{\min}}{2} = 38.9 \times 10^9 \text{ Pa}$$
$$\Delta E = \frac{E_{\max} - E_{\min}}{2} = 8 \times 10^9 \text{ Pa [1 s.f.]} \quad \text{[M1]}$$

Therefore,

$E \pm \Delta E = (39 \pm 8) \times 10^9$ Pa

$= (39 \pm 8) \times 10^6$ kPa [A1]

[A1] for correct units; kN m^{-2} or N m^{-2} or kPa or Pa (with correct values)

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H2 Physics Paper 3 Answers:

1a Units of Q

$$= \frac{m^3\left(kgm^{-1}s^{-2}\right)}{m}\sqrt{\frac{kgmol^{-1}}{\left(JK^{-1}mol^{-1}\right)(K)}}$$

$$= kgms^{-2}\sqrt{\frac{kg}{kgm^2s^{-2}}}$$

$$= kgs^{-1}$$

1b **(i)** Vernier callipers, zero error.

(ii)
$$V = \frac{\pi D^2}{4} \times h = \frac{\pi(8.4)^2}{4} \times (21.5) = 1191.48 \text{ cm}^3$$

$$\frac{\Delta V}{V} = 2\frac{\Delta D}{D} + \frac{\Delta h}{h} = 2\frac{0.01}{8.4} + \frac{0.1}{21.5} = 0.0070321$$

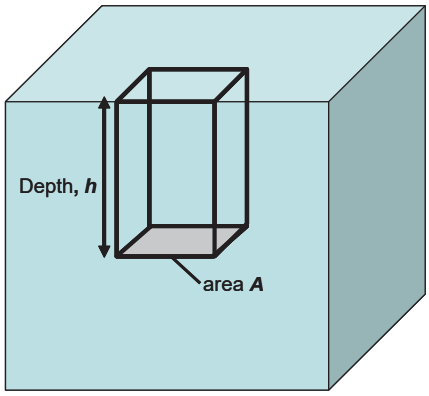
$$\Delta V = 8 \text{ cm}^3$$

$$V = (1191 \pm 8) \text{ cm}^3$$

2 Pressure is defined as force acting per unit area, where the force *F* acts perpendicularly to the area *A*.

Density of a substance ρ is defined as the mass *m* per unit volume *V*.
[B1 – for correct definition of pressure and density]

Consider a point at a depth *h* below the surface of a liquid in a container.



The pressure can be determined by finding the weight of the column of liquid acting above a very small area at that depth. [B1- for stating of correct column of liquid]

The weight *W* of the column of liquid is:

$W = m_{liquid}.g = \rho_{liquid}V_{liquid}g = \rho_{liquid}hAg$ [B1]

Therefore, the pressure *p* is: $P = \frac{Force}{Area} = \frac{W}{A} = \rho_{liquid}hg$ [B1]

[4]

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3 **(a)** Mass [B1]

(b) Impulse of a force is defined as the product of force and time of impact, and is equal to the change in momentum. [B1]

(c) **(i)** By conservation of momentum,
total momentum just before firing = total momentum just after firing

0 = momentum of bullets + momentum of man
[C1- for stating zero initial momentum]

$0 = 10 \times 1.0 \times 10^{-2} \times 750 - [90 - (10 \times 1.0 \times 10^{-2})] v$ [M1]

$v = 0.83426 \text{ m s}^{-1}$
$= 0.834 \text{ m s}^{-1}$ [A1]

[Note: deduct one mark for i & ii if students did not consider reduction in mass due to bullets being shot out]

(ii) Let average force exerted on man be F

$F\Delta t = \Delta p$

$F\Delta t$ = mass of man (final velocity of man – initial velocity of man)

$F(2.0) = [90 - (10 \times 1.0 \times 10^{-2})] (0.83426 - 0)$ [M1]

$F = 37.5$ N [A1]

.

(iii) **1.** Perfectly inelastic collision [B1]

2. Part of the loss in KE needs to account for the increase in gravitational potential energy of the block-bullet system besides the work done by frictional force. [M1]

Hence, the distance *x* would be shorter. [A1]

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4 **(a)** **(i)** The light is unpolarized, so $I_1 = 1/2\ I_o = 16$ W m^{-2} [B1]

(ii) When it emerges from the first polarizer the light is linearly polarized at 50°. The angle between this and the transmission axis of the second polarizer is 30°.

Therefore: using Malus Law,

$I_2 = 16 \cos^2 30°$. [M1]
$= 16 * 0.75$
$= 12$ W m^{-2} [A1]

(b)

Two images of different perspectives from the same scene are **perpendicularly polarised and projected** on the screen **simultaneously** B1

The viewer wears **glasses with left and right sides polarised perpendicularly to one another** (aligned with the plane of polarization of image). Each filter only allows light that are similarly polarised to pass through and block images in the perpendicular direction, so each eye sees a different image. B1

Hence, both eyes are able to see the same scene simultaneously but images are of slightly different perspectives, producing a 3D effect.

5 **(a)** The Principle of Superposition states that when two or more waves of the same kind overlap, the resultant displacement at any point at any instant is the vector sum of the displacements that the individual waves would have separately produced at that point and at that instant. (from notes) [B1]

(b) **(i)** Coherent waves (from laser) emerging from the slits will meet at a point on the screen with a phase/path difference. [B1]

When waves meet in phase with phase difference is n(2π rad)/ path difference is integer ×λ, constructive interference occurs. And at the points where the waves meet exactly out of phase (any equivalent explanation of minima e.g. (n+½)×360°), destructive interference occurs. [B1]

(ii) [1]

1.

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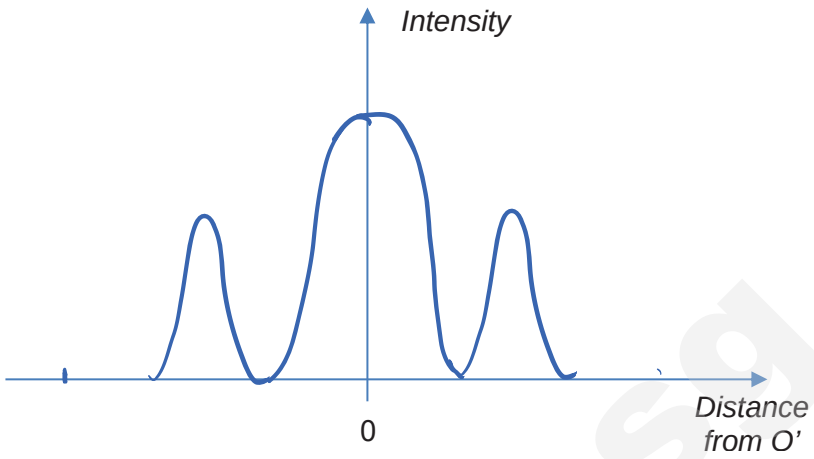

Student shows 3 maximas,
Decreasing intensity
Correct spacing
Symmetrical about O'
Any missing- minus 1 mark [B2]

2.

$\sin\theta = \frac{\lambda}{b}$

$\sin\theta = (4.5 \times 10^{-7})/(2.0 \times 10^{-6})$ [M1]

$\theta = 13.0°$

$\tan 13.0 = O'Y / 2.5$ [M0]

$O'Y = 0.577$ m [A1]

6 (a)

$R = \rho\frac{l}{A}$

$= (9.0)\left(\frac{7.5}{23}\right)$ [M1]

$= 2.9\ \Omega$

$I = \frac{V}{R}$

$= \frac{12}{2.9}$ [M1]

$= 4.1$ A [A1]

(b) sodium ion = right; chloride ion = left [B1]

(c) Number density of charge carriers

$= \left(\frac{1.7}{1000}\right)\left(6.02 \times 10^{23}\right)$ [M1]

$= 1.023 \times 10^{21} = 1.0 \times 10^{21}\text{cm}^{-3}$ [A1]

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(d) $I = nAvq$

$$v = \frac{I}{nAq}$$

$$= \frac{(0.5)4.1}{\left(1.0\times10^{21}\right)(23)(1.6\times10^{-19})} \qquad \text{[M1]}$$

$$= 5.6\times10^{-4} \text{ cm s}^{-1} \qquad \text{[A1]}$$

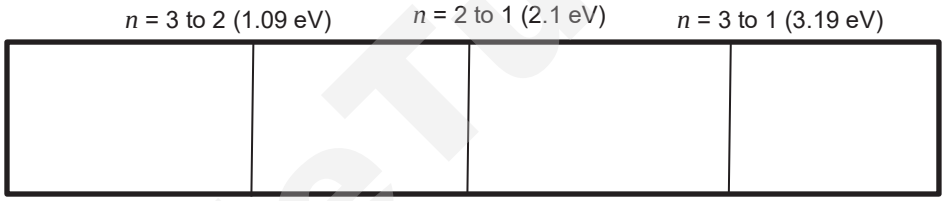
(e) **(i)** As chloride ions form chlorine gas, the number density of charge carriers (or the number of charge carriers per unit volume) decreases. [M1]

Hence the current decreases. [A1]

(ii) As the emf of the cell is constant, the net external electric field between the electrodes remains constant. [M1]

Hence the average drift velocity of the ions remains constant. [A1]

7 **(a)** **(i)**



[B1] - three spectral lines with labelled transitions
[B1] – correct relative positions

(ii) Energy of incident electron = 3.19 + 0.24 [M1]
= 3.43 eV [A1]

(iii)



Fig. 7.4

The **photons of energy 2.1 eV emitted from sodium/ emitted from de-excitation n= 2 to 1 of sodium**, in discharged tube will be **absorbed** to cause exitation (from n = 1 to n = 3) **in the cool gas** . [B1]

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As this gas de-excites (transition n=3 to 2, n =3 to 1 and n= 2 to 1), photons are emitted . While the **photons are re-emitted to produce three spectral lines, the intensity would be relatively weak**. Hence three faint lines are observed [B1]

The **other two photons of energy emitted by sodium gas** (from transitions n= 3 to 1 and n = 3 to 2) **will not be absorbed by the cool gas** and pass through resulting in two bright lines on the detector. [B1]

(b) (i) Electrons have a wave-like nature. [B1]

(ii)

Kinetic energy of electron at wall, E_k = 600 eV = 9.6 x 10^{-17} J

Momentum of electron at wall, p

$$p^2 = 2mE_k$$

$$p = \sqrt{2(9.11\times10^{-31})(9.6\times10^{-17})}$$ [M1]

de Broglie wavelength λ of electron at wall

$$= \frac{h}{p}$$

$$= \frac{6.63\times10^{-34}}{1.32\times10^{-23}}$$ [M1]

$$= 5.01\times10^{-11}\ \text{m}$$

$$d = \frac{\lambda D}{a}$$

$$= \frac{(5.01\times10^{-11})(0.240)}{272\times10^{-9}}$$ [M1]

$$= 4.42\times10^{-5}\ \text{m}$$ [A1]

(ii) As accelerating potential increase, **velocity and momentum** of electron reaching the wall **increase.** Its **de Broglie wavelength decreases**, and hence the fringe separation of interference pattern decrease. [M1]

Distance *d*, the separation between the centres of adjacent bright spots, will **decrease**. [A1]

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8 (a) (i) The electric field strength at a point in an electric field is the electric force per unit positive charge on a small test charge placed at that point. [B1]

(b) (i) [M1]

$$F_E = q\frac{V}{d} = ma$$

$$a = \frac{(1.6\times10^{-19})(\frac{100}{0.50\times10^{-2}})}{(9.11\times10^{-31})} = 3.5\times10^{15}\text{ m s}^{-2}$$

[A1]

(ii) [M1]

$$v_y = u_y + a_y t$$

$$2.3\times10^{6} = 0 + (3.5\times10^{15})(\text{t})$$

[A1]

$$t = 6.6\times10^{-10}\text{ m s}^{-1}$$

(iii) Since electric force on electron is downwards, the magnetic force has to be directed upwards. [M1] [A1]

Using Fleming's LHR, the magnetic field is directed out of the page.

(v)

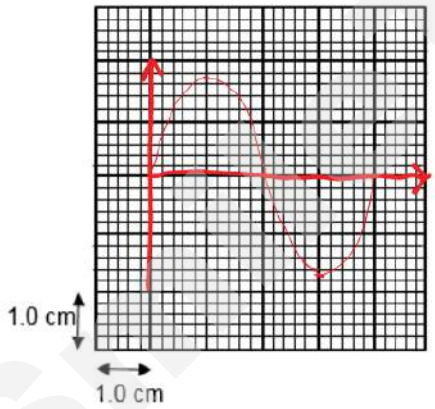
1. $100\pi = 2\pi f$

frequency = 100 /2 = 50 Hz [B1]

Period = 1/50 = 0.02 s

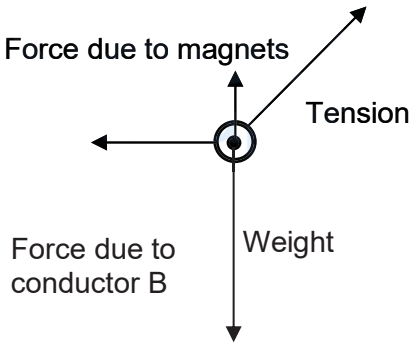
2. When $V_{r.m.s.}$ = 60 V,

V_0 = ($\sqrt{2}$)(60) = 85 V



[B1] Calculation of V_0
[B1] Correct sketch

8 (c) (i)



For each force drawn, it must be labelled and of the correct length [B2]

(ii) $F = BIL = (3.2\times10^{-3})(5.0)(0.20) = 3.2\times10^{-3}\text{N}$ [B1]

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(iii) Magnitude of T_x = Magnitude of force due to conductor B [B1]

$$|T_x| = |BIL| = \frac{\mu_o I}{2\pi d}(I)(L) = \frac{4\pi \times 10^{-7}}{2\pi(0.010)}(5.0)(5.0)(0.20)$$

$$= 1.0 \times 10^{-4}\text{N}$$

$T_y + F_{magnets} = mg$

$$T_y = mg - F_{magnets} = (\frac{0.35}{1000} \times 9.81) - 3.2 \times 10^{-3}$$ [B1]

$$= 2.3 \times 10^{-4}\text{N}$$

[B1]

Tension = $\sqrt{(1.0 \times 10^{-4})^2 + (2.3 \times 10^{-4})^2} = 2.54 \times 10^{-4}$

$$\tan(\frac{\theta}{2}) = \frac{T_x}{T_y} = \frac{1.0 \times 10^{-4}}{2.3 \times 10^{-4}}$$ [B1]

$$\theta = 47^0$$

(iv) The claim is false. The force due to the magnets acts downwards on the conductor **B**. Hence for the same tension, the mass of conductor **B** is less than **A**. [A1] [M1]

At equilibrium, the sum of the weight and the force due to the magnets balances the vertical component of tension.

$$T\cos\left(\frac{\theta}{2}\right) = mg + F_{magnets}$$

$$mg = T\cos\left(\frac{\theta}{2}\right) - F_{magnets}$$

9 **(a)**

	alpha	beta	gamma
mass	4*u*	1/1840*u*	massless
nature	particle	particle	EM radiation
penetrating ability	Stopped by few cm of air	Stopped by few mm of aluminium	Stopped by few cm of lead

1 mark each for each property. Students must get both answer correct for each property to get that mark.

(b) **(i)** **X**: alpha

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Y: gamma

Z: beta

Each mistake to deduct 1 mark.

(ii) 1. Radiation **X** are emitted with the same KE/ energy. [A1]

2. Radiation **Z** are emitted with different speeds. [A1]

(iii) If there are only two products produced during the decay process, the speed of radiation **Z** must be fixed. [B1]

Since radiation **Z** is emitted with varying speeds, by Principle of Conservation of Momentum and Energy, there must be a third particle produced in the decay process. [B1]

(c) **1.** The number of nuclear decays per unit time occurring in the source. [A1]

2. Time taken for half the original number of radioactive nuclei to decay. [A1]

(d) **(i)** Activity, A = 2 Bq

Since $A = \lambda N$ [M1]

$$\frac{\ln 2}{t_{\frac{1}{2}}} N = A$$

$$N = \frac{A t_{\frac{1}{2}}}{\ln 2} = \frac{(2)(1.42\times10^{19})}{\ln 2} = 4.1\times10^{19} \text{ particles}$$ [M1]

Mass of $^{238}_{92}\text{U}$ = $\dfrac{(4.1\times10^{19})(238)}{6.02\times10^{23}}$ [M1]

$= 1.6\times10^{-2}$ g [A1]

(ii) By conservation of momentum,

$m_\alpha v_\alpha = m_{Th} v_{Th}$ [M1]

$$\frac{1}{2}(m_\alpha v_\alpha)^2 = \frac{1}{2}(m_{Th} v_{Th})^2$$

$$m_\alpha KE_\alpha = m_{Th} KE_{Th}$$

$$KE_{Th} = \frac{m_\alpha}{m_{Th}} KE_\alpha = \frac{4u}{234u} 4.18 = 0.0715 \text{ MeV}$$ [M1]

Total energy released $= 0.0715 + 4.18 = 4.25$ MeV [A1]

(e) 1. The radioactive nuclide should have a short half-life. [B1]

2. The radioactive nuclide should produce gamma radiation during the decay process. [B1]

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 2

H2 Physics 9749/4

Paper 4 Practical

12 September 2017
2 hours 30 minutes

Class	Reg Number

Candidate Name: _____

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **ALL** the questions.

You are allowed 1 hour to answer Questions 1 and 2; and you are allowed another 1 hour to answer Question 3.

Question 4 is a question on the planning of an investigation and does not require apparatus.

Write your answers in the space provided in the question paper. The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, Question 1&2, Question 3, Question 4 are to be submitted separately.

The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

Examiner's Use	
1	
2	
3	
4	
Total	/55

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This booklet consists of 17 printed pages.

1 In this experiment, you will investigate the equilibrium of a wooden rule.

(a) **(i)** Attach masses to the apparatus as shown in Fig. 1.1.

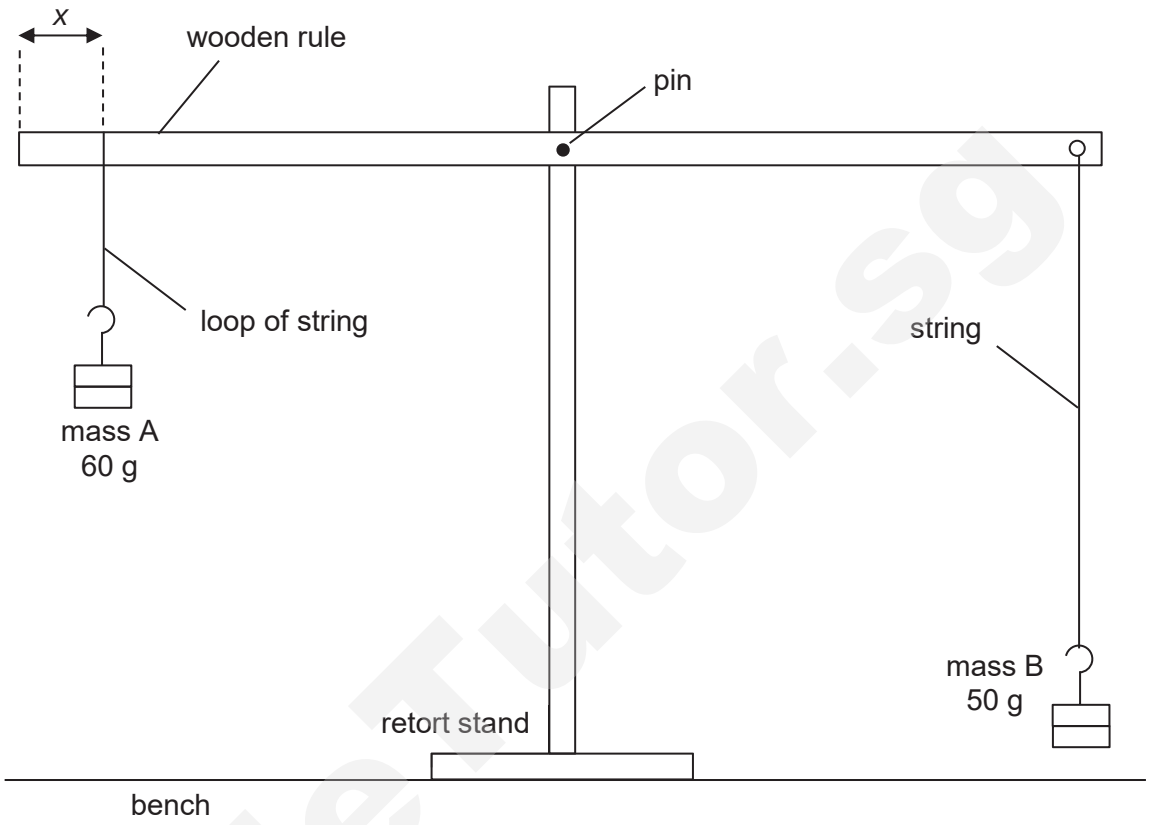

Fig. 1.1

Mass A is suspended from the wooden rule using a loop of string. The distance between the loop of string and the nearest end of the wooden rule is *x*.

(ii) Change *x* until the wooden rule is balanced and approximately parallel to the bench. Measure and record *x*.

x = 9.3 cm [1]

Accepted range: up to 15 cm

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(b) **(i)** Remove both masses. Clamp the pulley to the retort stand using two wooden blocks.

Thread the string for mass B over the pulley, and then attach the masses again, as shown in Fig. 1.2.

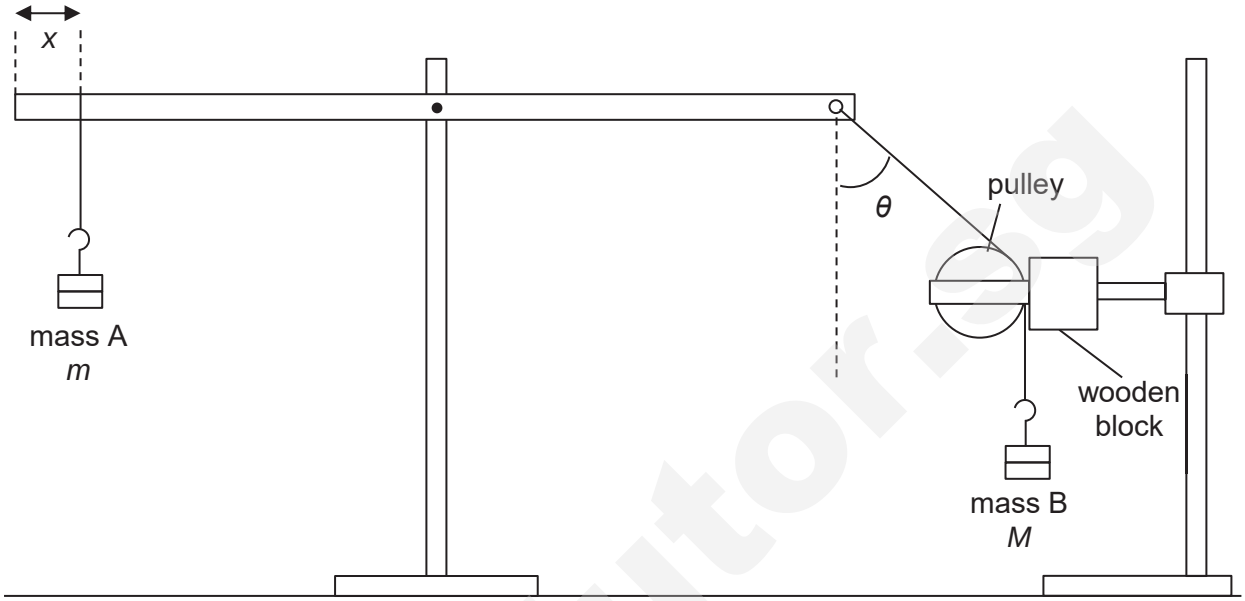

Fig. 1.2

(ii) Transfer 10 g from mass A to mass B.

(iii) With x at the same value as **(a)(ii)**, adjust the position of the pulley until the wooden rule is approximately parallel to the bench.

Measure and record the angle θ that the string for mass B makes with the vertical, as shown in Fig. 1.2.

$\theta_1 = 47°$
$\theta_2 = 47°$
$\langle\theta\rangle = 47°$

θ = 47° [1]
evidence of repeated readings
θ presented to the nearest degree

(iv) Estimate the percentage uncertainty in your value of θ.

$$\text{Percentage Uncertainty} = \frac{\Delta\theta}{\theta} \times 100\%$$
$$= \frac{3}{47} \times 100\% = 6.4\% \text{ (2 s.f.)}$$

percentage uncertainty = 6.4% [1]
Δθ (2 to 5 degrees, to 1 s.f)
Percentage uncertainty to 2 s.f.

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(v) Record the mass m of mass A and mass M of mass B.

m = 50 g

M = 60 g [1]

(vi) Calculate the value of $\frac{m}{M}$.

$\frac{m}{M} = \frac{50}{60} = 0.83$

$\frac{m}{M}$ = 0.83 [1]

(c) It is suggested that the cos θ is directly proportional to $\frac{m}{M}$.

Take further measurements to investigate this suggestion and explain whether your results support the suggested relationship.

Present your measurements and calculated results clearly.

Collection of data and calculation of *k* (with correct sf and units):

$\frac{m}{M} \propto \cos\theta$

$\therefore \frac{m}{M} = k\cos\theta$ where k is a constant of proportionality

m / g	M / g	θ_1 / °	θ_2 / °	$\langle\theta\rangle$ / °	$\frac{m}{M}$	cosθ	K
50	60	47	47	47	0.83	0.68	1.22
50	70	56	55	56	0.71	0.56	1.27

Criterion: Results support the suggested relationship if percentage difference of k is smaller than percentage uncertainty of θ of 6.4% (or student's stated criterion)

Calculation of % difference:

$$\text{Percentage difference of k} = \frac{1.27 - 1.22}{1.22} \times 100\% = 4.1\%$$

Conclusion:

Since the percentage difference of k is smaller than percentage uncertainty of θ of 6.4, hence the result supports the suggested relationship.

.....

.....

..... [4]

[Total: 9 marks]

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2 The resistance of a light-dependent resistor (LDR) changes when it is illuminated with light of different intensities.

In this question, you will investigate how the light detected by a LDR depends on the thickness of an absorber.

(a) **(i)** Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

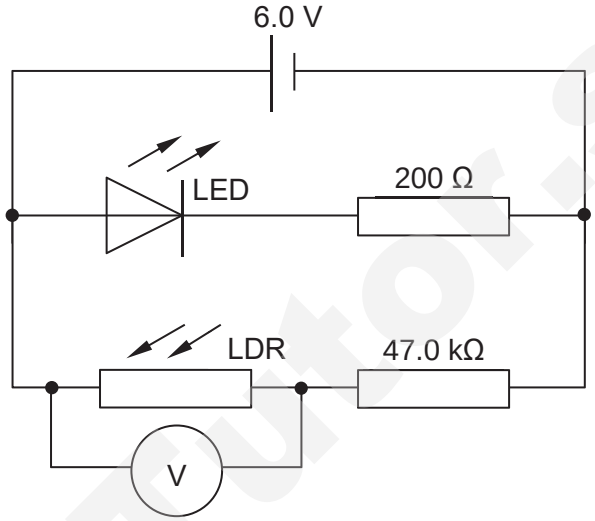

Fig. 2.1

(ii) You are provided with a black straw of approximate length of 4 cm.

(iii) Use the straw and clear adhesive tape to make a cylinder that fits neatly over the LDR and LED.

Cut the cylinder into two halves of approximately 2 cm each and fit the 2 cylinders over the LDR and LED, as shown in Fig. 2.2.

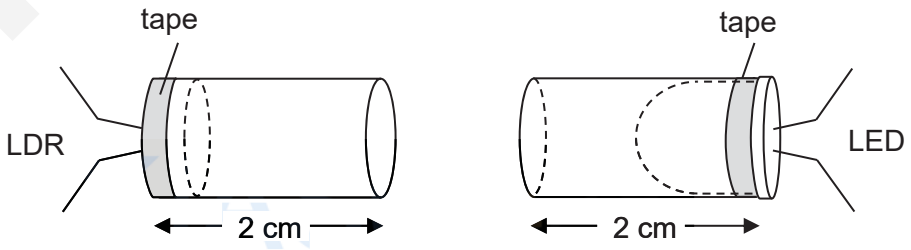

Fig. 2.2

(b) Place the cylinders together, as shown in Fig. 2.3.

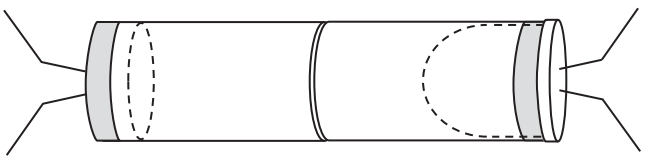

Fig. 2.3

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Record the voltmeter reading V_0.

V_0 = 0.28 V [2]

Accept up to 3.0 V (cannot be negative)
Correct d.p and units

(c) Fold the sheet of tracing paper in half four times so that you have 16 layers.

(i) Measure and record the thickness of these 16 layers.

d_1 = 1.00 mm
d_2 = 0.97 mm
<d> 0.99 mm

thickness of 16 layers = 0.99 mm [1]

Repeated readings
Correct d.p and units
Accepted range: 0.5 mm to 5 mm

(ii) Determine the thickness t of one layer of tracing paper.

$$t = \frac{< d >}{16}$$
$$= \frac{0.99}{16}$$
$$= 0.062 \text{ mm}$$

t = 0.062 mm [1]

Correct calculation with correct sf and units

(iii) Estimate the percentage uncertainty in your value of t.

Since $t = \frac{< d >}{16}$ $\quad \therefore \frac{\Delta t}{t} = \frac{\Delta d}{d}$

$$\text{Percentage Uncertainty} = \frac{\Delta d}{< d >} \times 100\%$$
$$= \frac{0.02}{0.99} \times 100\%$$
$$= 2.0\% \text{ (2 s.f.)}$$

percentage uncertainty = 2.0% [1]

Δd >= 0.02 mm (accept up to 0.05 mm) for 16 layers (to 1 s.f.)
Percentage uncertainty to 2 sf

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(d) **(i)** Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4.

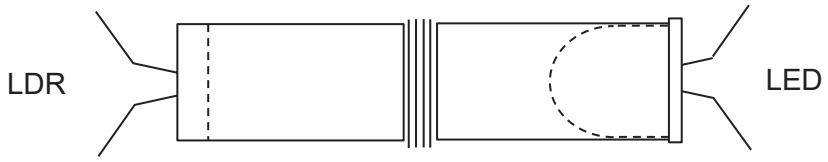

Fig. 2.4

Record the voltmeter reading *V*.

V = 1.29 V [1]
Correct dp and units

(ii) Repeat **(d)(i)** using eight layers of tracing paper.

V = 2.15 V [1]
Correct dp and units
$V_o < V(di) < V(dii)$

(e) **(i)** State and explain two significant sources of error or limitations of the procedures for this experiment.

Any two of the following
- 2 readings not enough (to draw a conclusion)
- Alignment of LDR and LED (not just alignment of cylinder)
- Stray light coming in because the cylinders are not sealed / external light hits LDR
- Difficult to hold all together therefore voltage reading fluctuates
- Separation between LED and LDR changes as paper is added.

[2]

(ii) Suggest two improvements that could be made to the experiment and explain how this addresses the errors identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure.

Corresponding improvements
- Take many readings and plot a graph / find many values of k
- Guide used / line on desk / adjust LED/LDR to get max voltage / method of fixing LED/LDR in cylinder
- Dark room / black cloth over / lights off and curtains drawn / black box / black tape
- Method of fixing. Eg, clamp/plasticine / tape
- Pre-slots in tube

[2]

Do not allow:
- 'varying thickness of paper, scratches on tracing paper, zero error on micrometer'
- 'repeated readings, parallax error'
- 'use a computer to improve the experiment'

Ignore separation of layers affects light getting through and squashing of paper for micrometer reading.

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(f) Suggest changes that could be made to the experiment to investigate how the light detected by a LDR depends on the angle between the polarising axes of a pair of polarizing filters.

You may assume that a pair of *unmarked* polarizing filters is available.

You may draw a diagram to show how the apparatus would be arranged.

- Replace the tracing paper with 2 polarising filters
- Mark the axis where the polarizing filters give the minimum V reading. Polarising axes of the 2 polarisers are parallel at this angle.
- Vary angle between polarizing axes and measure the angle with a protractor.

.....

.....

.....

..... [3]

[Total: 14 marks]

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Turn over for Question 3

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3 In this experiment you will investigate the relationship between the current in a copper wire and the orientation of a magnet suspended near to the copper wire. The magnet (with a pointer attached) has been suspended as shown in Fig. 3.1.

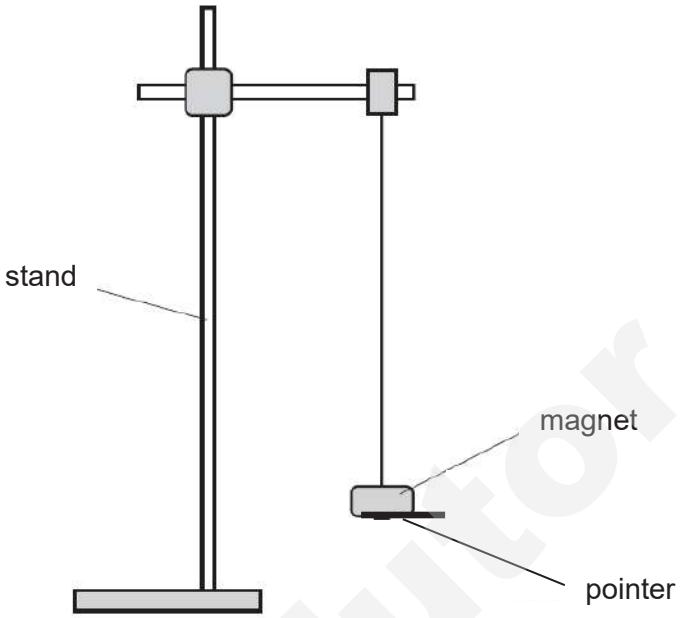

Fig. 3.1

A piece of straight copper wire has been taped to one edge of a 50 cm rule and a protractor attached to the centre of the rule. You should not disturb the copper wire or the protractor from their positions on the rule during the course of the experiment.

(a) (i) Set up the circuit shown in Fig. 3.2.

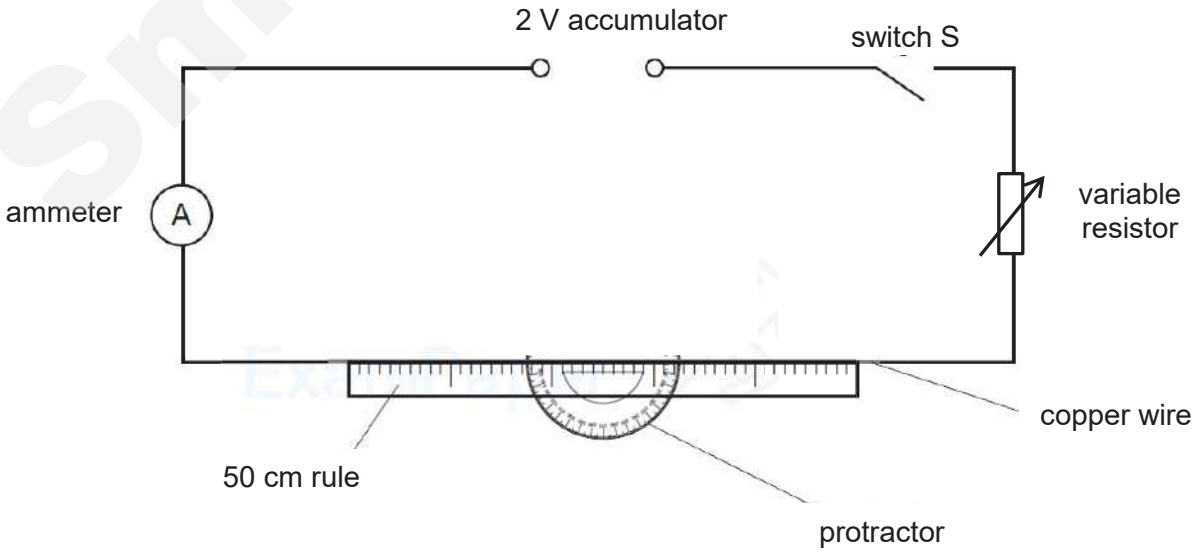

Fig. 3.2

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(ii) Place the rule just below the magnet such that the pointer is at most 5 mm above the top of protractor. The pointer should be perpendicular to the wire and the centre of the protractor directly below the point of suspension. The arrangement is shown in Fig. 3.3.

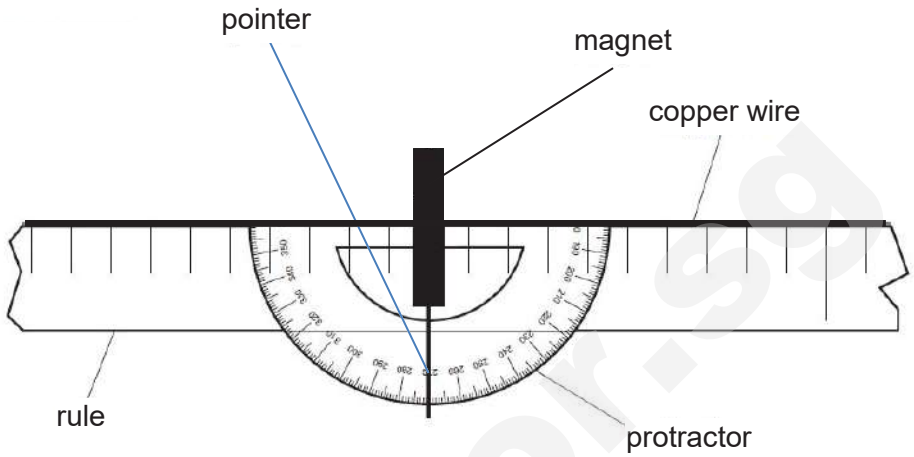

Fig. 3.3 (top view)

(iii) Close switch S.

(iv) Adjust the current until the pointer shows a measurable deflection. Slow down the motion of the magnet by touching it. When the pointer is steady, measure and record the angle of deflection θ and the current I.

$$\theta = \frac{8+8}{2} = 8°$$

θ = 8°

I = 1.34 A [1]

[1] – correct dp with units

(v) Estimate the percentage uncertainty of θ.

$$\frac{\Delta\theta}{\theta} = \frac{2}{8} \times 100\% = 25\%$$

[1] – correct sf, $2° \le \Delta\theta \le 4°$ due to oscillation of magnet

percentage uncertainty of θ = 25% [1]

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(vi) Vary the resistance of the variable resistor and repeat **(iv)** to obtain further sets of readings for θ and I. The current should not exceed about 4 A.

θ_1 / °	θ_2 / °	θ_{ave} / °	I / A	tan θ
8	8	8	1.34	0.14
11	10	11	2.05	0.194
17	17	17	2.70	0.306
20	19	20	3.35	0.364
21	22	22	3.98	0.404
28	28	28	4.80	0.532

[2]- 6 sets of readings without assistance
[1]- repeated reading
[1]- heading and units
[1]- d.p. of raw data
[1]- correct sf
[1]- correct calculations

[7]

(vii) Open switch S.

(b) The formula which relates θ and I is

$$\tan\theta = A\,I + B$$

where A and B are constants.

Plot a graph to determine the values of A and B.

Plot a graph of $\tan\theta$ against I. If the equation is valid, a straight line graph with gradient A and vertical intercept B will be obtained.

Gradient = $\frac{y_2 - y_1}{x_2 - y_1}$ =0.11

A=0.11 A^{-1}

Intercept= - 0.015

B = - 0.015

[1]- Statement
[1]- gradient
[1]- A with correct units and sf
[1]- B (no units) with correct sf

A = ...

B = ... [4]

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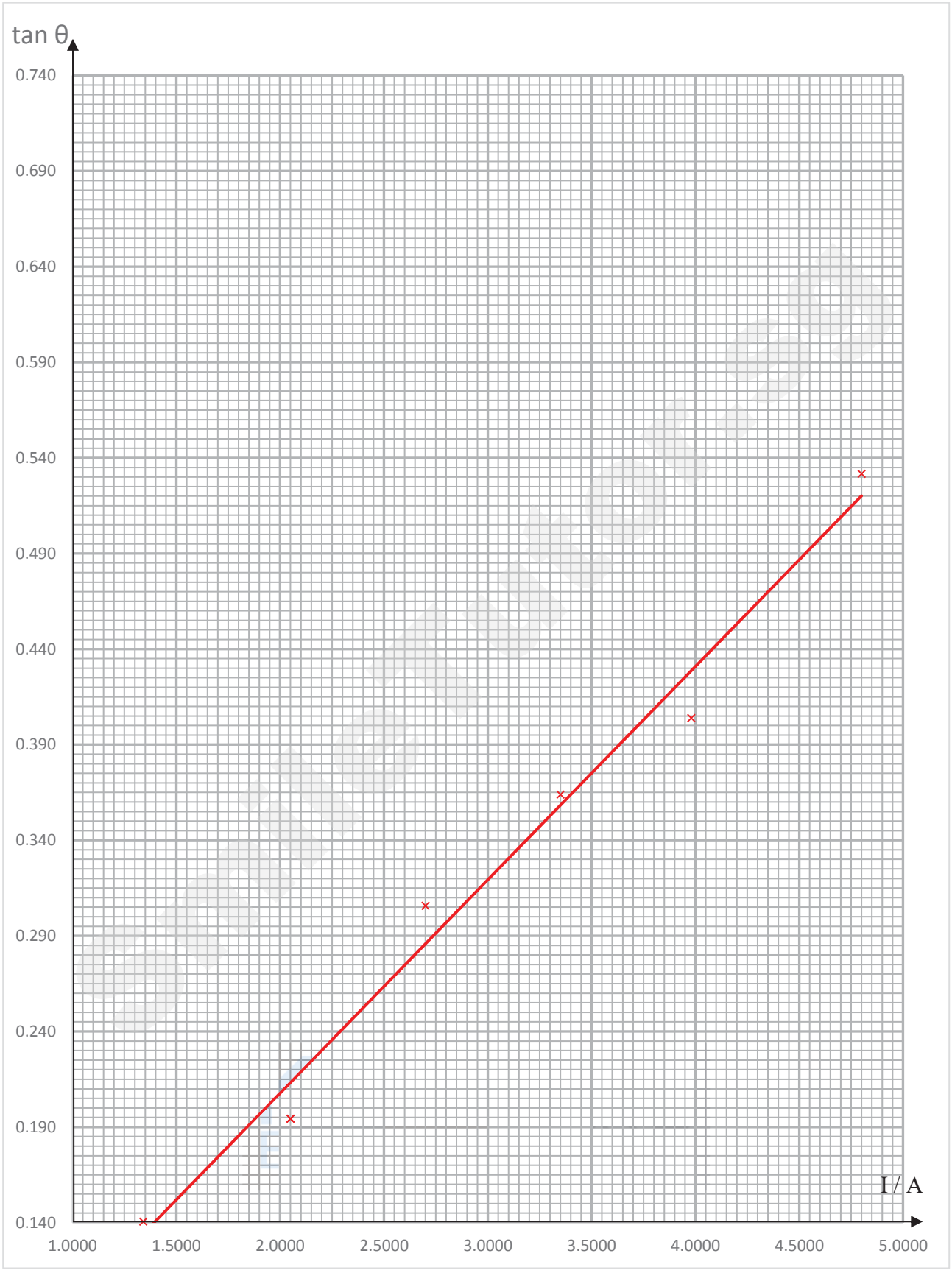

[1]- Axis labelled with units, good scale
[1]- correctly plotted points
[1]- Best fit line

[3]

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(c) Comment on any anomalous data or results that you may have obtained. Explain your answer.

[1]- Correct identification and explanation of any anomalous point [1]

(d) **(i)** Use the results from your experiment to calculate a value for θ when the current in the copper wire is 15 A.

$\tan \theta = 0.11\ (15) + (-0.015)$

$\theta = 59°$

[1]- value calculated correctly

$\theta = \underline{59°}$ [1]

(ii) Give one reason why it may be difficult to verify this experimentally.

Any one of the following:

- Heating problem with wire
- Fuse may blow if max current is exceeded
- Do not allow vague answers such as it is dangerous

[1] Possible reason stated

..... [1]

(e) It is known that constant A is affected by the magnetic flux density due to the wire. On the graph grid on page 12, sketch a second graph to represent the results if distance between the magnet and the wire is increased. Label this graph **Z**. [1]

$\tan \theta = A I + B$

Increasing distance will reduce magnetic flux density. Though it is not stated how A will be affected by reduction in flux density, however it should be deduced that when flux density is very small, $\tan \theta$ will be a constant. Hence A should approach zero.

[1]- smaller gradient but same intercept.

[Total: 20 marks]

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4 Each of the propellers on a drone consists of two or more blades connected to a motor shaft. As the motor rotates air is drawn through the blades. This results in a thrust on the propeller, hence lifting the drone. Fig. 4.1 shows a propeller used in a drone. The speed of rotation of the motor is determined by the power supply it is connected to.

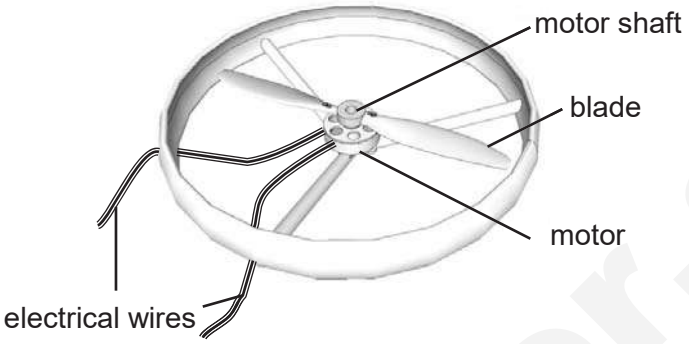

Fig. 4.1

A student suggests that the average thrust T on the propeller depends on the rotational speed ω of the blade, the blade angle θ, and the density of air.

The relation between the average thrust T, ω, and θ may be written in the form

$$T = k\omega^a \sin^b \theta$$

where k, a, b are constants.

You are provided with the following apparatus.

- a number of propellers with different blade angles indicated,
- tachometer (an instrument that measures the rotational speed of a shaft)
- electronic balance

You may also use any of the other equipment usually found in a physics laboratory.

Design an experiment to determine the values of k, a, b.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account, you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedures to be followed,

(d) how the values of k, a and b are determined from your readings,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[Total: 12 marks]

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Q4 Proposed Mark Scheme

Annotation	Rubrics	Max	Actual
Diagram (D)	**(D1)** Labelled diagram showing connection of propeller to a workable circuit. Propeller is placed on an electronic balance.	1	
Basic Procedure (BP)	**(BP1)** By varying rotational speed ω and blade angle θ independently, obtain and measure different values of thrust T to obtain at least 6 sets of readings each.	1	
Control (C)	**(CV1)** Maintain density of air by keeping temperature of room constant. Achieve by conducting experiment in temperature-controlled room (e.g. air-conditioned room). **(CV2)** Keep rotational speed ω constant (**for M2**) by measuring ω and varying the voltage to achieve required ω.	1	
Methods of Measurement (M)	**(M1)** Keeping blade angle θ constant, vary rotational speed ω by changing voltage (e.g. varying power supply or rheostat) across motor. Measure ω using a tachometer. Record the rotational speed. **(M2)** Keeping rotational speed ω constant (by keeping voltage constant), vary blade angle θ by using propeller of different blade angles. Record the angle. **(M3)** Place propeller on electronic balance and tare before turning on power. Turn on power and take balance reading m. Thrust is given by magnitude of mg.	3	
Analysis (A)	**(A1)** Plot a suitable graph of lg T vs lg ω (keeping θ constant). gradient = a ; vertical-intercept = $b\lg(\sin\theta)+\lg k$ **(A2)** Plot a suitable graph of lg T vs lg $(\sin\theta)$ (keeping ω constant). gradient = b ; vertical-intercept = $a\lg\omega+\lg k$ **(A3)** Obtain k by taking average of k values from (A1) and (A2).	3	
Reliability of Experiment (R) **Method** and **reason**	**(R1)** Elevate the propeller so as not to obstruct air flow during operation. **(R2)** Using different θ and ω to obtain several a, b, and/or k. Find average of the constants. **(R3)** When varying ω first find the maximum ω that will cause propeller to lift off / spin out of control. Maximise datasets of ω within this range. **(R4)** Place propeller upside-down so that the air will be push out from the top when turned on. To prevent air from exerting force on balance.	2	
Safety (S)	**(S1)** Do not touch the propeller when it is rotating to avoid getting cut by blade. **(S2)** Weigh down propeller (e.g. using heavy wood blocks) so that it does not spin out of control when turned on causing damage to equipment.	1	
	Total	12	

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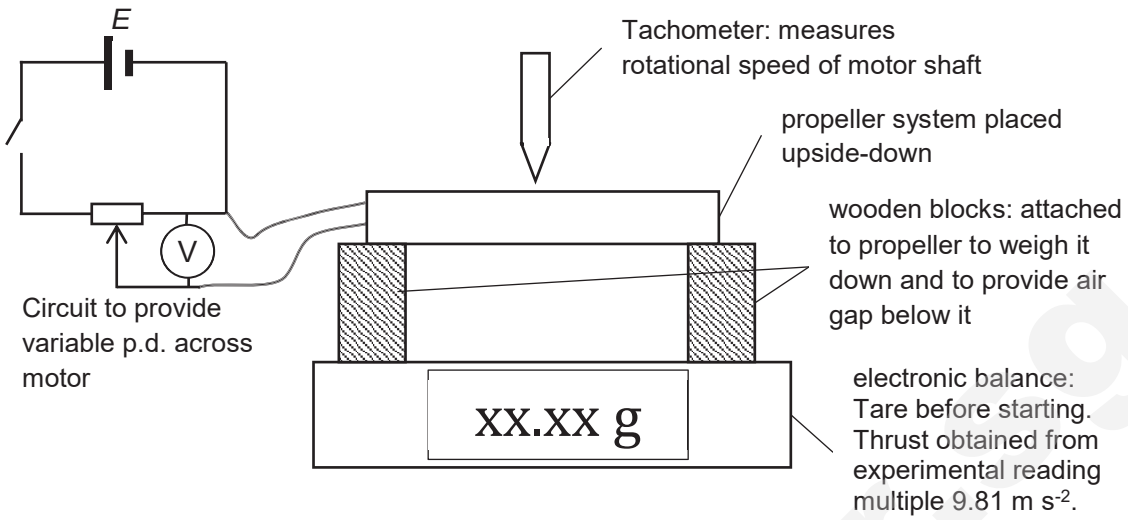
Diagram: [D1]



Independent variable: Blade angle θ and rotational speed ω
Dependent variable: Thrust T
Control variables: Density of air

Procedure:

1. Conduct the experiment in a temperature-controlled room (e.g. air-conditioned room) so as to keep the temperature constant in order to maintain the density of air. **[CV1]**
2. Set up the apparatus as shown in the diagram above.
3. To prevent air drawn by propeller from exerting force on balance, the propeller should be placed upside-down so that the air will be push out from the top when turned on. **[R4]**

Vary ω, *keeping* θ *constant*

4. Record down the angle $\theta_{constant}$ of the blade.
5. Close the switch and increase voltage across the motor by adjusting the rheostat until just before the whole propeller spins out of control. Using the tachometer find this maximum rotational speed ω_{max}. **[R3]**
6. Open the switch. Tare the electronic balance.
7. Close the switch. By varying the voltage across the motor using the rheostat, obtain a lower value of rotational speed ω. Measure this with a tachometer and record it down. **[M1]**
8. Take the magnitude of reading m shown on the electronic balance. The thrust T can be obtained by $T = mg$, where g is the acceleration of freefall. **[M3]**
9. Repeat steps 6 to 8 for total of six sets of data by varying ω through adjusting voltage and using the same blade angle $\theta_{constant}$. Maximise the range between 0 and ω_{max}.

Vary θ, *keeping* ω *constant*

10. Select a rotational speed $\omega_{constant}$ from previous part.
11. Change the propeller to be of blade angle θ. Record it down. **[M2]**
12. Tare the electronic balance.

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13. Close the switch. Using the tachometer to measure the rotational speed, adjust the voltage until the rotation speed is at $\omega_{constant}$. **[CV2]**
14. Take the magnitude of reading m shown on the electronic balance. The thrust T can be obtained by $T = mg$, where g is the acceleration of freefall. **[M3]**
15. Repeat steps 11 to 14 for total of six sets of data by changing the propeller for different blade angle θ and using the same rotational speed $\omega_{constant}$.

Analysis

16. Using data from varying ω (θ constant), plot a straight line graph of lg T vs lg ω. The gradient will give a and the vertical intercept will give $b\lg(\sin\theta)+\lg k$ **[A1]**
17. Using data from varying θ (ω constant), plot a straight line graph of lg T vs lg $(\sin\theta)$. The gradient will give b and the vertical intercept will give $a\lg\omega+\lg k$ **[A2]**
18. k can be obtained from the vertical intercept of steps 16 and 17. **[A3]**
19. Using different θ and ω to obtain several a, b, and k. Find average of the constants. **[R2]**

Safety Precaution

- Do not touch the propeller when it is rotating as it might cut. **[S1]**
- Weigh down the propeller so that it does not spin out of control causing damage to equipment. **[S2]**

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Candidate Name: _____

Class	Adm No

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2017 Preliminary Examination II

Pre-University 3

H2 PHYSICS **9646/01**

Paper 1 Multiple Choices

Thursday **21 Sep 2016** **1 hour 15 minutes**

Additional Materials: OMR Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your name, class, admission number and NRIC number on the OMR Answer Sheet in the spaces provided.

There are **forty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate OMR Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

The use of approved scientific calculator is expected, where appropriate.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

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1 What is the approximate power of a light bulb at home?

A 0.1 W **B** 10 W **C** 1000 W **D** 10000 W

2 In the determination of the amount of charge, Q, moving across a conductor I is the current reading from an ammeter and t is the time recorded on a stop watch.

$I \pm \Delta I$ = (2.00 ± 0.05) A
$t \pm \Delta t$ = (6.00 ± 0.01) s

What is the percentage uncertainty of the value of Q calculated from these readings?

A 2.5% **B** 2.7% **C** 3.0% **D** 4.2%

3 While sitting on a tree branch 12.0 m above the ground, a monkey drops a chestnut. When the chestnut has fallen 2.0 m, the monkey throws a second chestnut vertically downwards.

What is the initial speed of the second chestnut if both chestnuts were to land at the same time?

A 2.5 ms^{-1}
B 4.1 ms^{-1}
C 8.4 ms^{-1}
D 14.5 ms^{-1}

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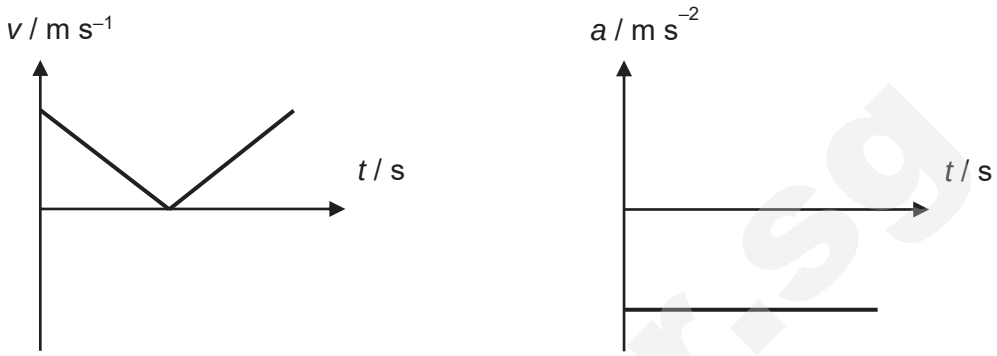
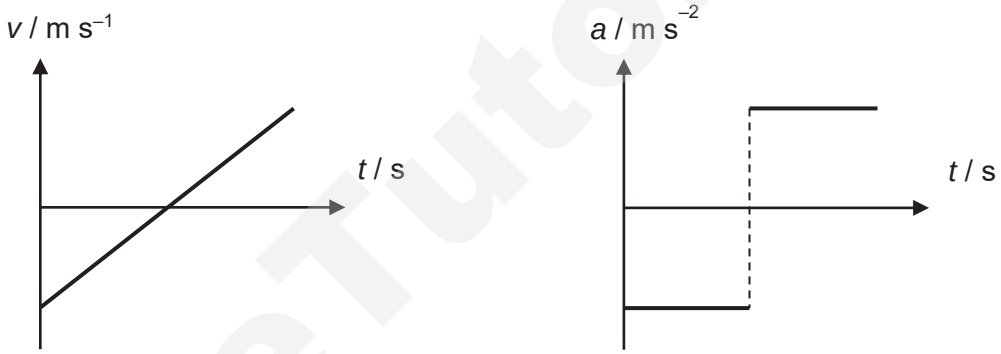
4 An electron decelerates uniformly in an electric field, comes to a stop, and accelerates at the same rate that it decelerated earlier.

Which of the following velocity-time and acceleration-time graphs best represent the above motion?

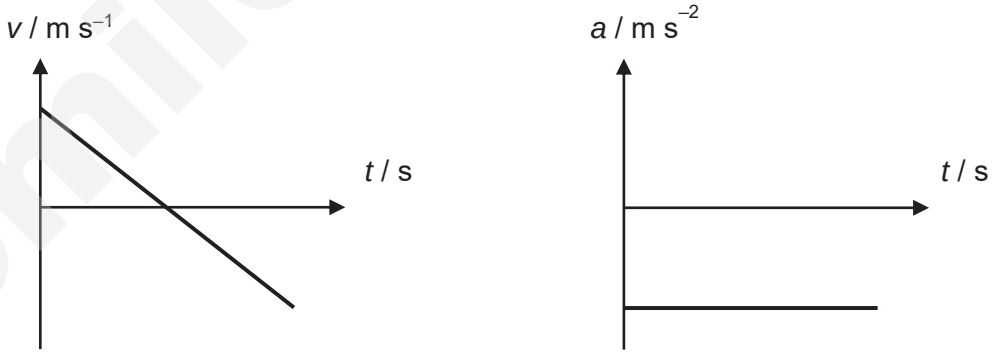
A



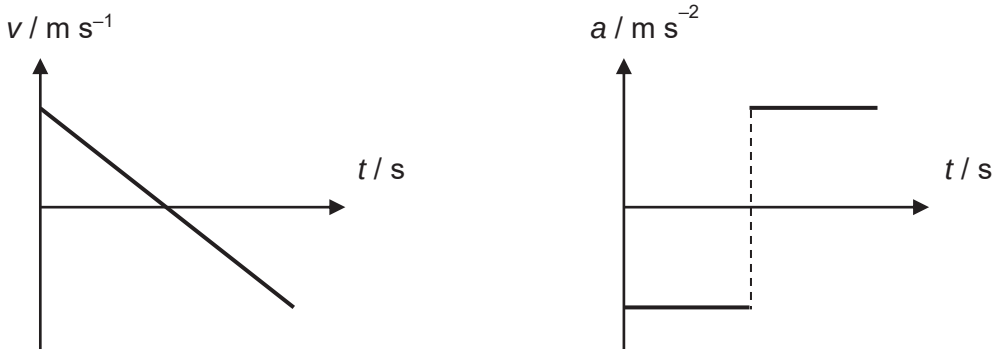
B



C



D



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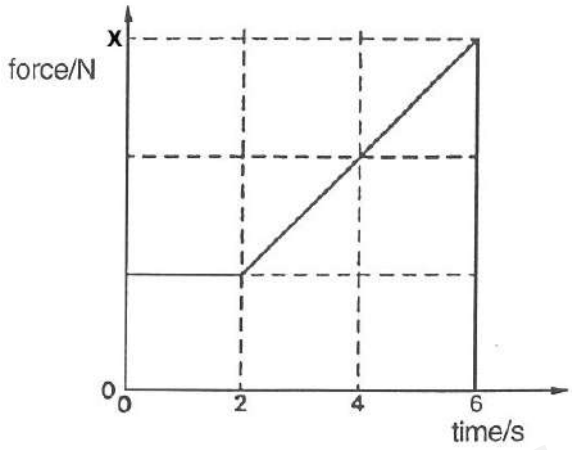
5 A force which varies with time as shown in the figure acts on a body.



Assuming that the body is moving in a straight line, and given that the body gained momentum of 20 kg ms^{-1} at the end of 6 seconds, what is the value of x?

A 2 N

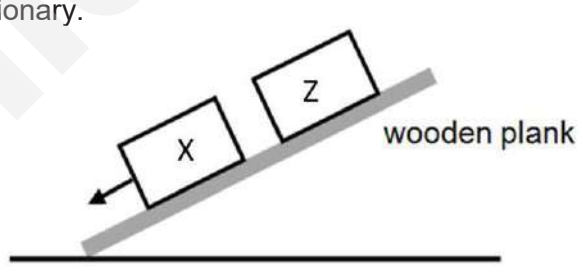
B 3 N

C 6 N

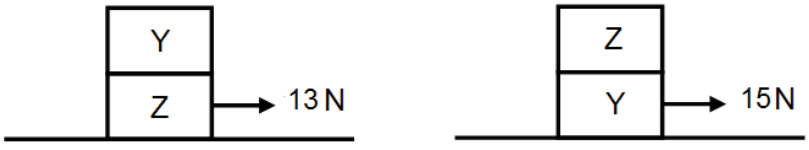
D 10 N

6 Blocks X, Y and Z have the same dimensions but are made of different materials.

Blocks X and Z are placed on a wooden plank. When the plank is tilted, block X slides down while block Z remains stationary.



When block X is put on top of block Y, the force required to maintain constant velocity is 13 N. When block Y is put on top of block X, the force required to maintain constant velocity is 15 N.



Which of the following gives the roughness of the blocks in decreasing order?

A YZX

B ZXY

C XZY

D ZYX

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7 A rod of length 1 m has non-uniform composition, so that the centre of gravity is not at its geometrical centre. The rod is laid on supports across two top-pan balances as shown in the diagram. The balances (with no zero error) give readings of 360 g and 240 g.



Where is the centre of gravity of the rod *relative to its geometrical centre*?

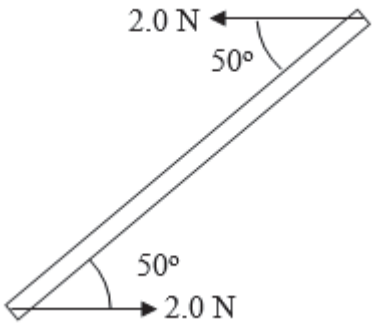
A 0.10 m to the left

B 0.10 m to the right

C 0.25 m to the left

D 0.25 m to the right

8 A ruler of length 0.30 m is pivoted at its centre. Equal and opposite forces of 2.0 N are applied to the ends of the ruler creating a couple as shown below.



What is the magnitude of the torque of the couple on the ruler when it is in the position shown?

A 0.19 N m **B** 0.23 N m **C** 0.38 N m **D** 0.46 N m

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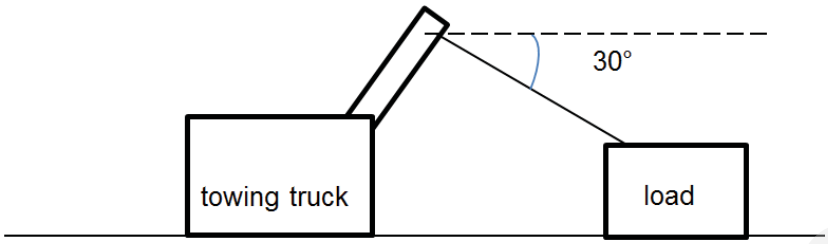
9 The diagram below shows a tow truck pulling a load at constant velocity horizontally to the left. The cable makes an angle of 30° with the horizontal and the tension in the cable is found to be 2500 N.



What is the work done by the cable when it has travelled 15 m?

A zero

B 18800 J

C 32500 J

D 37500 J

10 The top end of a spring is attached to a fixed point and a mass of 4.2 kg is attached to its lower end. The mass is released and after bouncing up and down several times it comes to rest at a distance 0.29 m below its starting point.

Which option gives the gain in the gravitational potential energy of the mass E_p and the gain in the elastic potential energy of the spring E_s?

	E_p / J	E_s / J
A	-12	-12
B	-12	+6
C	+12	-12
D	+12	+6

11 An artificial satellite travels in a circular orbit about the Earth in a uniform circular motion.

Which of the following statement is **not true**?

A The velocity of the satellite is constant throughout the motion.

B The period of the motion is constant.

C There is zero work done by the satellite during the orbit.

D The acceleration of the satellite is always directed towards the centre of the orbit.

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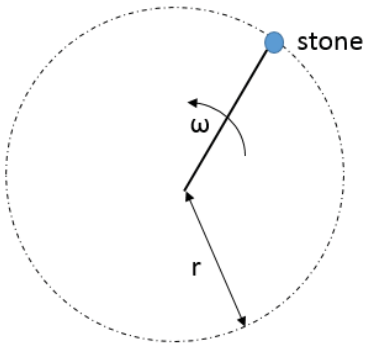
12 A stone of mass m is attached to a string. The stone is rotating in a vertical circle of radius r with a constant angular speed ω as shown.



The acceleration of free fall is g.

What is the minimum magnitude of the tension in the string during one revolution of the stone?

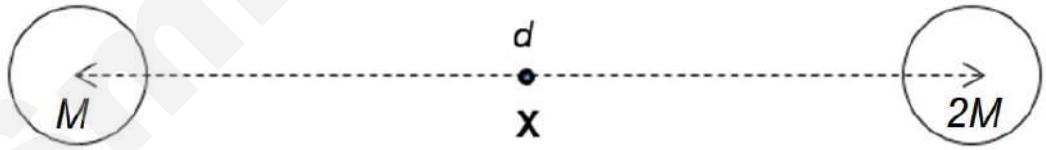
A $m (r \omega^2 - g)$

B $m r \omega^2$

C $m g$

D $m (g - r \omega^2)$

13 The centers of two isolated spherical stars each of radius *R* are separated by a distance *d* as shown. One star has mass M, and the other has mass 2M.



Point **X** is mid-way between the stars.

Which expression gives the net gravitational force due to the two stars that acts on a mass *m* placed at point **X**?

A zero

B $\frac{2GMm}{d^2}$ to the right

C $\frac{4GMm}{d^2}$ to the left

D $\frac{4GMm}{d^2}$ to the right

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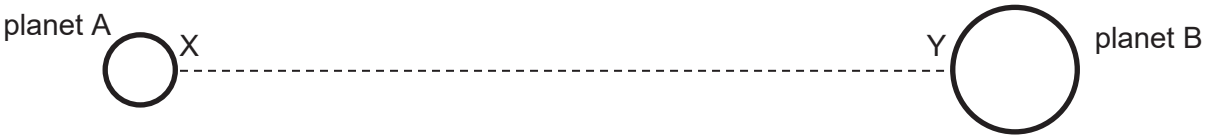
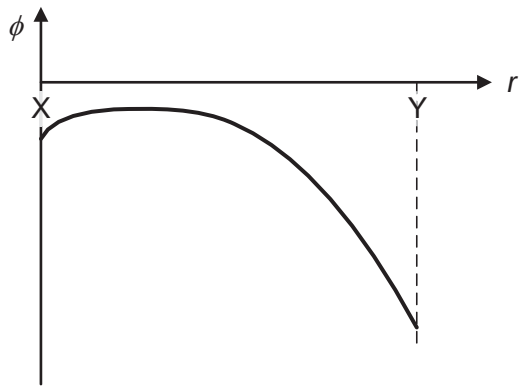
14 The mass of planet A is 8 times smaller than that of planet B, while the radius of planet A is half that of planet B. Line XY joins the surface of planet A to the surface of planet B.

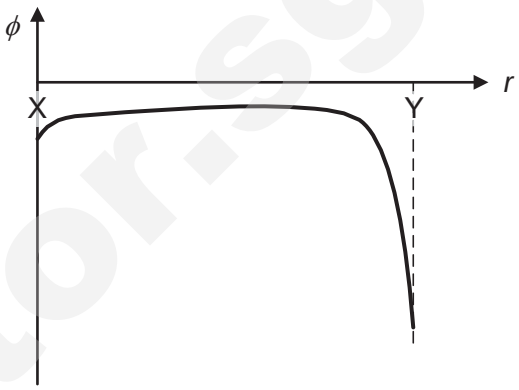


Which of the following graphs represents the variation of gravitational potential ϕ with distance r from the surface of planet A?

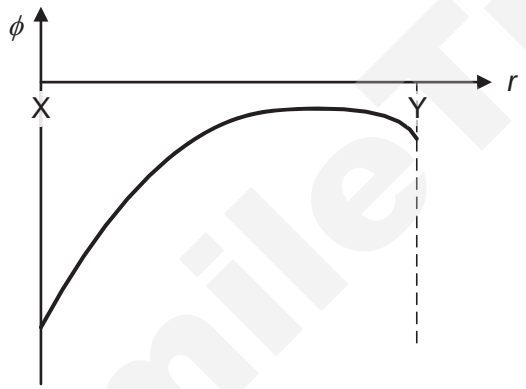
A



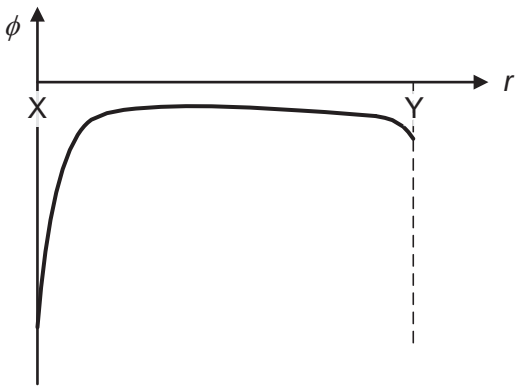
B



C



D



15 A body in simple harmonic motion makes n complete oscillations in one second.

Which of the following expression represents the angular frequency of the motion?

A n rad s^{-1} **B** πn rad s^{-1} **C** $2\pi n$ rad s^{-1} **D** $1/n$ rad s^{-1}

16 An object of mass 150 g executes simple harmonic motion with amplitude of 2.5 cm. At a displacement of 1.0 cm from the equilibrium, its kinetic energy is 0.62 J.

What is the natural frequency of the oscillation?

A 18 Hz **B** 20 Hz **C** 22 Hz **D** 24 Hz

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17 The table gives the results from an experiment to determine the specific heat capacity of a liquid by an electrical method.

mass of liquid heated	1.5 kg
initial liquid temperature	300 K
final liquid temperature	357 K
electrical power of heater	1.0 kW
duration of heating	200 s

Which of the following is the specific heat capacity of the liquid?

A 2.4 J kg^{-1} K^{-1}

B 2400 J kg^{-1} K^{-1}

C 2.0 J kg^{-1} K^{-1}

D 2000 J kg^{-1} K^{-1}

18 The kinetic theory of gases may be used to derive the following expression relating the pressure P and the volume V of a gas to the root-mean-square speed of its molecules:

$$P = \frac{1}{3}\frac{Nm}{V} < c^2 >.$$

What does the term $\frac{Nm}{V}$ represent in this expression?

A The density of the gas

B The mass of the all the gas molecules

C The total number of molecules in one mole of gas

D The total number of molecule present in volume V

19 A transverse wave of speed 0.50 m s^{-1} travels in a stretched string. The displacement *y* of particles along the stretched string with time is given by the expression.

$$y = 30 \cos 0.35\, t$$

Given that *t* is in second (s) and *y* in metre (m), what is the wavelength of the wave?

A 1.7 m **B** 7.3 m **C** 9.0 m **D** 11.4 m

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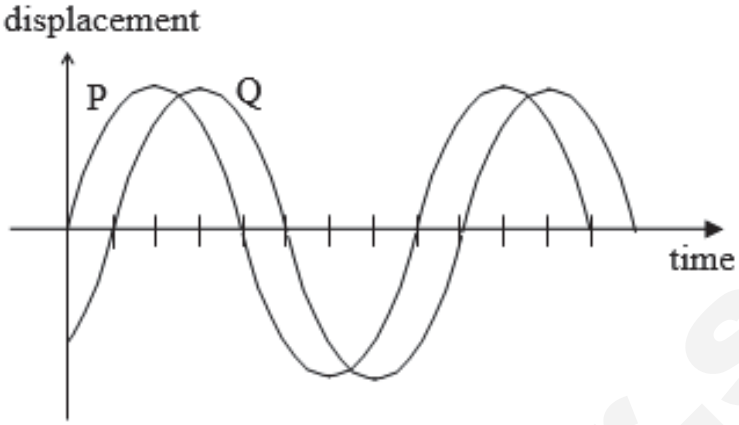
20 The diagram shows two waves P and Q.

What is the phase difference between the two waves?



A $\pi/8$ rad **B** $\pi/4$ rad **C** $\pi/2$ rad **D** π rad

21 When a two-slit arrangement is set up to produce interference fringes on a screen using monochromatic source of green light, the fringes are found to be too close together for convenient observation.

In which of the following ways would it be possible to increase the separation of the fringes?

A Decrease the distance between the screen and the slits.

B Increase width of each slit.

C Have a larger distance between the two slits.

D Replace the light source with a monochromatic source of red light

22 A diffraction grating ruled with 5000 lines per cm is illuminated with white light.

If the wavelength for yellow light and violet light are 600 nm and 400 nm respectively, which one of the following statements is NOT correct?

A The central image is white.

B The second-order image of the yellow light coincides with the third-order image of violet light.

C There is no fourth-order image for yellow light.

D The red end of the first-order spectrum is closer to the central image than the violet end of the first-order spectrum.

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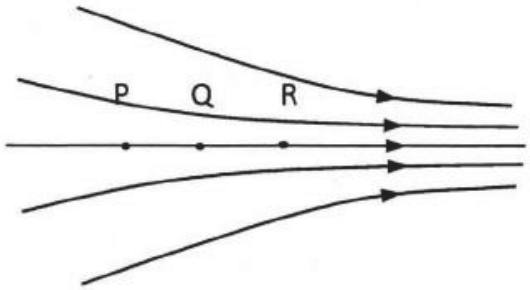
23 The figure below shows electric field lines with points PQR on one of the field lines. The distance PQ = QR.



Which of the following statement is *not true*?

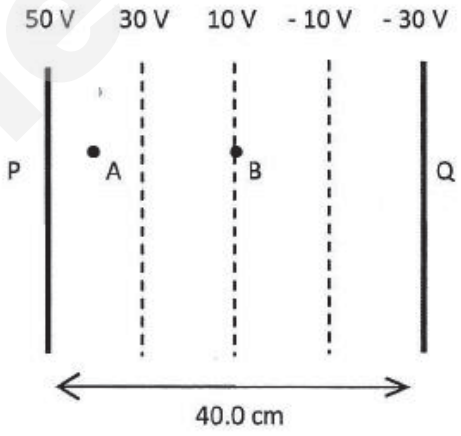
A P has a higher potential than R.

B A negative charge placed at Q will experience an electric force acting towards P.

C The field strength at P is larger than R.

D A proton will experience electric force of the same magnitude as an electron when placed at Q.

24 An electron is released at point B and it moves towards point A.



Determine the speed of the electron when it reaches point A.

A 1.26×10^6 ms^{-1}

B 3.25×10^6 ms^{-1}

C 5.43×10^6 ms^{-1}

D 7.58×10^6 ms^{-1}

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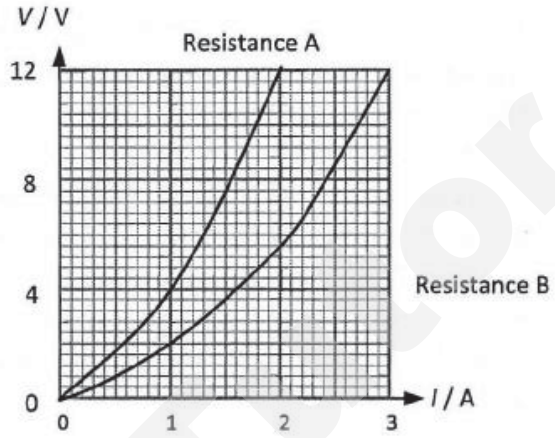
25 The total energy dissipated in a circuit when a charge of 5.0 C flows from the battery is 20 J.

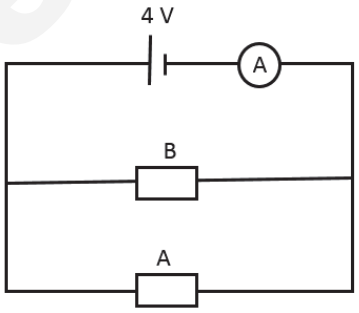
What is the e.m.f. of the battery?

A 4.0 V
B 10 V
C 50 V
D 100 V

26 Resistor A and B have the following V-I characteristic.



What is the current reading on the ammeter if resistor A and B are connected in the circuit as shown below?



A 1.0 A **B** 1.6 A **C** 2.6 A **D** 3.0 A

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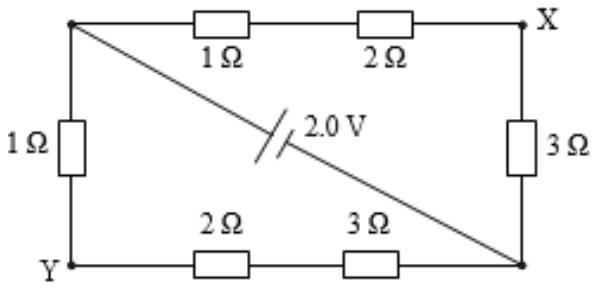
27 Six resistors are connected to a 2.0 V cell of negligible internal resistance as shown in the figure below.

What is the potential difference between X and Y?



A 0.67 V

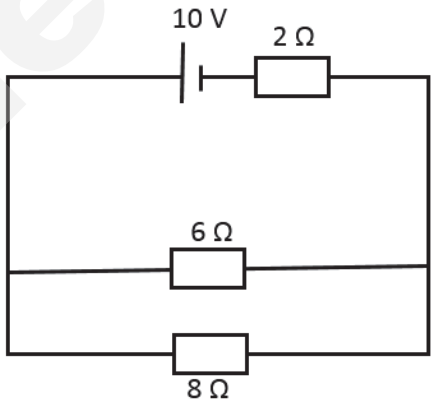
B 0.89 V

C 1.33 V

D 1.67 V

28 In the circuit below, the battery has negligible internal resistance.

What is the magnitude of the current passing through the 6.0 Ω resistor?



A 0.62 A **B** 0.88 A **C** 1.1 A **D** 1.7 A

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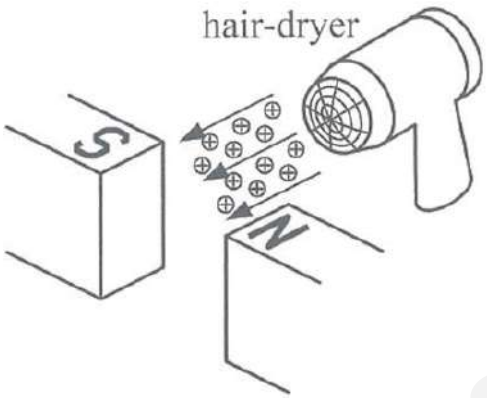
29 A hair dryer discharges hot air that contains many positively charged ions, and the motion of these ions constitutes an electric current. The diagram below illustrates the hot air being directed between the poles of a strong magnet.



In which direction will the ions be deflected?

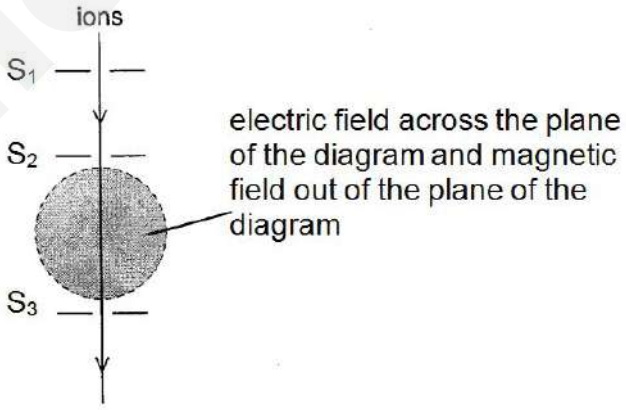
A Vertically downwards

B Vertically upwards

C Towards the north pole N

D Towards the south pole S

30 The diagram shows part of an apparatus in which positive ions pass through slits S_1, S_2 and S_3.



Between S_2 and S_3, they pass through mutually perpendicular magnetic and electric fields, the intensities of which may be varied.

What is the function of the mutually perpendicular fields between S_2 and S_3?

A To accelerate the ions to high velocity

B To select ions of a particular charge

C To select ions of a particular mass

D To select ions of a particular velocity

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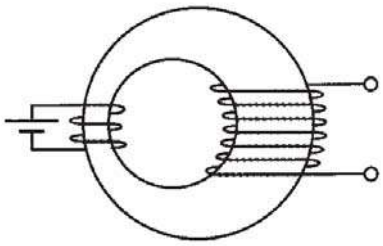
31 Two coils are wound around a soft iron ring of variable cross-section. One coil has 3 turns and is connected to a d.c. supply. The other coil has 7 turns.



Which of the following is the same inside each coil?

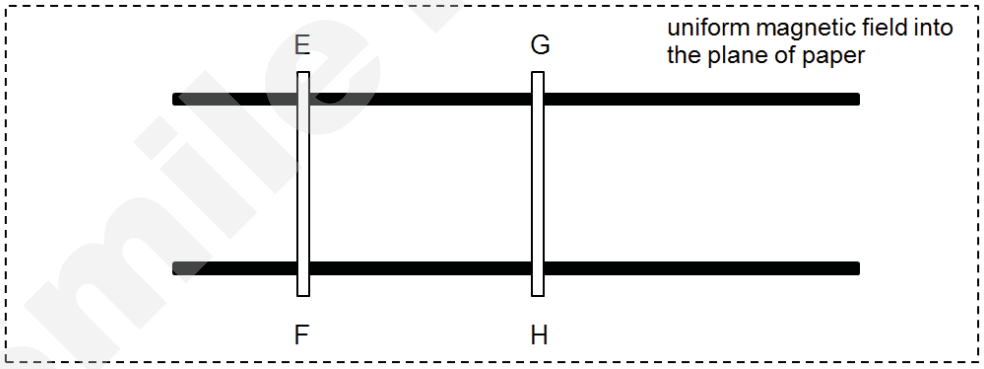
A magnetic flux density

B magnetic flux

C magnetic flux linkage

D magnetic field

32 Two light metal rods EF and GH are initially at rest on two smooth horizontal conducting rails of negligible resistance. A uniform magnetic field *B* is directed perpendicularly into the paper.



Rod EF is given a nudge so that it slides to the left.

In which direction would rod GH move?

A To the left

B To the right

C To the left, then to the right

D To the right, then to the left

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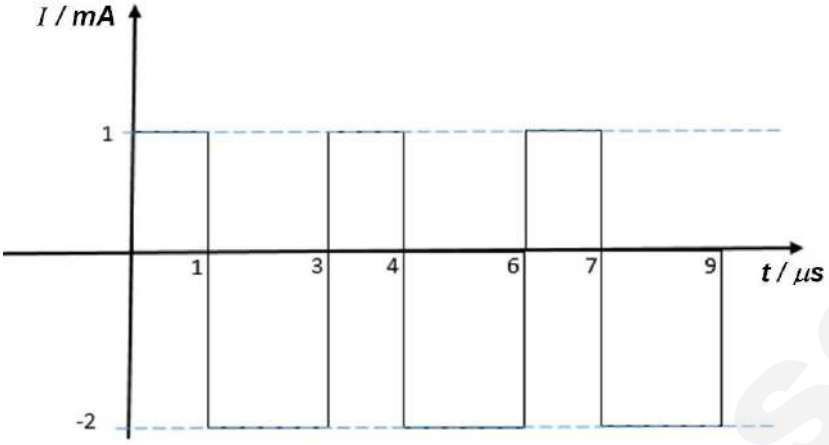
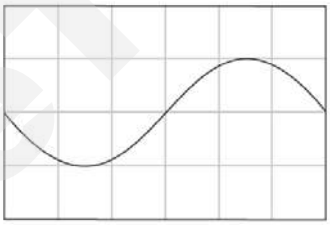
33 Figure below shows an a.c. current.



What is the root-mean-square value for this current?

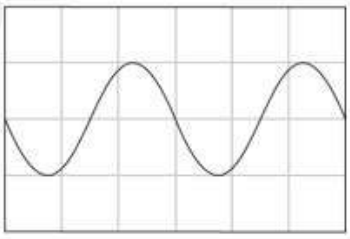
A 1.25 mA **B** 1.73 mA **C** 3.32 mA **D** 5.48 mA

34 An a.c generator is rotating at an angular frequency of ω. The waveform produced on the screen of a cathode-ray oscilloscope (c.r.o.), when the c.r.o. is connected to measure the e.m.f. generated, is shown below.

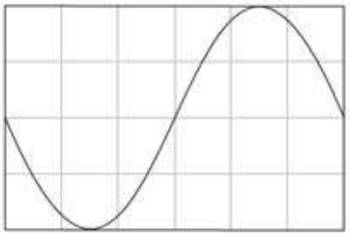


Which of the following diagrams shows the waveform displayed on the c.r.o. when the generator rotates at an angular frequency of 2ω?

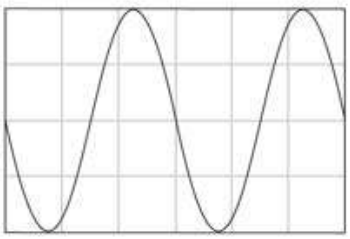
A



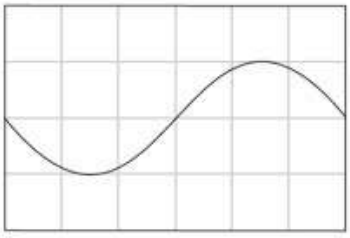
B



C



D



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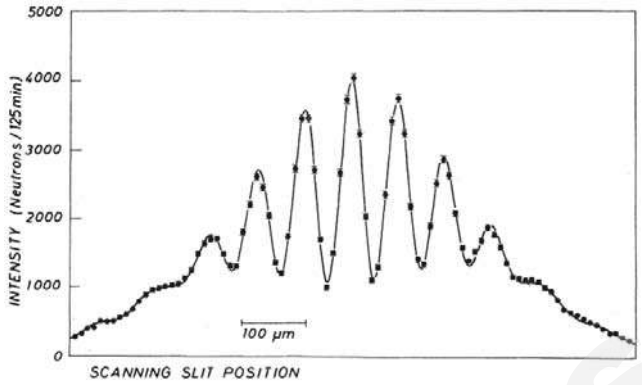
35 Figure below shows the experimental results of a double-slit experiment done using neutrons.



Double-slit interference pattern made with neutrons.

(A. Zeilinger, R. Gähler, C.G. Shull, W. Treimer, and W. Mampe, Reviews of Modern Physics,

C_{60} molecules (each of mass 720 times that of a neutron) with the same kinetic energies of the neutrons are used to do the experiment in the same experimental condition.

What will happen to the fringe spacing?

A increase by 720 times.

B increase by $\sqrt{720}$ times.

C decrease by 720 times.

D decrease by $\sqrt{720}$ times.

36 An electron and a proton approach a potential barrier of height U and thickness d. The transmission coefficient T is given in the relation below:

$$T \; \alpha \; e^{-2kd} \quad \text{where } k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$$

The value of e^{-2kd} for the electron is in the order of 10^{-5}, and that for the proton is in the order of 10^{-186}.

Which statement best describes the electron and proton?

A The electron will never reach the other side of the barrier.

B The electron has a higher chance of reaching the other side of the barrier.

C The proton has a higher chance of reaching the other side of the barrier.

D The proton will never reach the other side of the barrier.

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37 Which of the following statements about intrinsic semiconductors is true?

A It can behave like an insulator at low temperature.

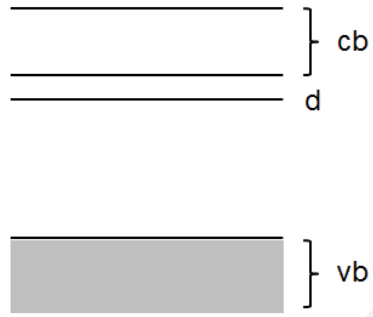
B The donor energy level lies just below the conduction band.

C The valence band and conduction band overlap.

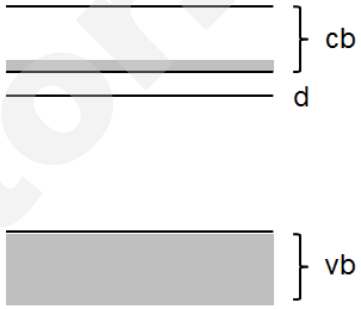
D There is an energy gap of 5 eV to 10 eV between the valence and conduction band.

38 Which diagram illustrates the valence band vb, the conduction band cb, and the dopant level d in an intrinsic semiconductor doped with electron-deficient impurity atoms that is at zero Kelvin? (Electrons are represented by the shaded region.)

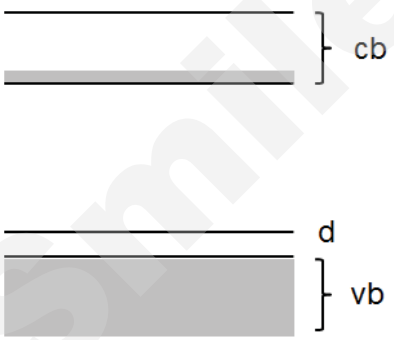
A



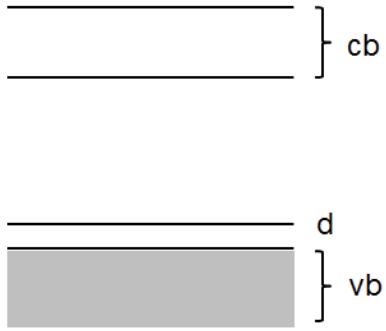
B



C



D



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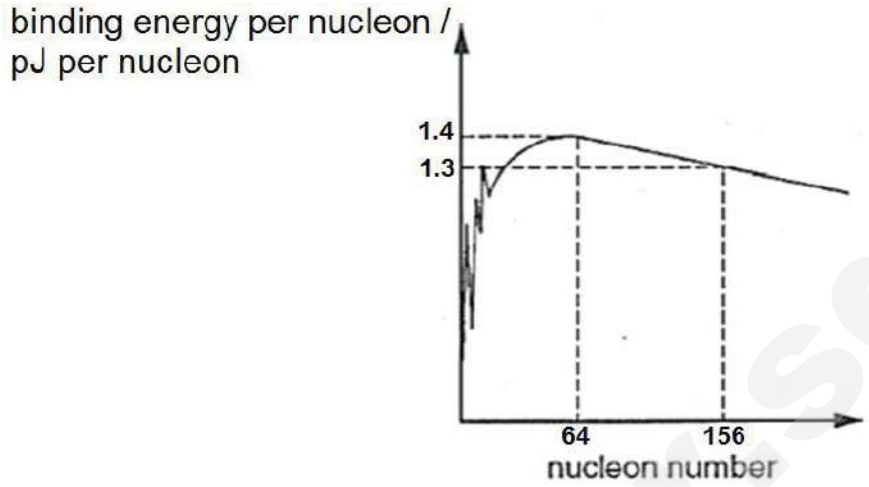
39 The sketch graph shows how the binding energy per nucleon varies with the nucleon number of naturally occurring nuclides.



What is the total binding energy of the nuclide $^{156}_{64}Gd$?

A 83 pJ

B 90 pJ

C 203 pJ

D 218 pJ

40 Samples of two radioactive nuclides, X and Y, each have equal activity A_o at time t = 0. X has a half-life of 20 years and Y a half-life of 15 years.

The samples are mixed together.

What will be the total activity of the mixture at t = 30 years?

A $0.10A_o$ **B** $0.25A_o$ **C** $0.30A_o$ **D** $0.60A_o$

End of Paper

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Candidate Name: _____

Class	Adm No

H

millennia institute

2017 Preliminary Examination II
Pre-university 3

H2 Physics **9646/02**
Paper 2 Structured Questions

Monday **11 Sep 2017** **1 hour 45 minutes**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and admission number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total	

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

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Section A (60 Marks)

Answer **all** questions

It is recommended that you spend about 1 hour 15 minutes on this section.

1 A 4.00 kg mass is attached to a vertical rod by means of two cords. When the system rotates about the axis of the rod, the cords are extended as shown in Fig. 1.1 and the tension in the upper cord is 70.0 N.

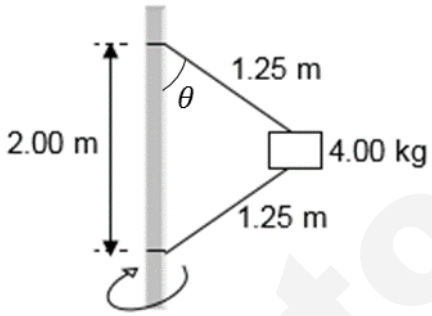

Fig. 1.1

(a) Draw a clearly labelled free body diagram of the 4.00 kg mass.

[1]

(b) Show that the tension in the lower cord is 21.0 N.

[2]

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(c) Show that the system makes around 41 revolutions in one minute.

[3]

(d) Find the number of revolutions per minute at which the lower cord just goes slack.

number of revolutions per minute = ... min^{-1} [3]

(e) Explain quantitatively what happens to angle θ if the number of revolutions per minute is less than that calculated in **(c)**.

.....

.....

.....

.....[2]

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2 In Fig. 2.1, S_1 and S_2 are two small loudspeakers that emit sound waves of the same intensity and wavelength. A microphone for detecting sound intensity is placed at point P such that $S_1P = S_2P$

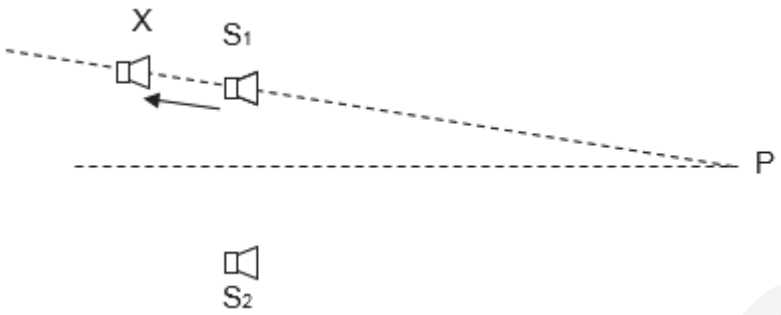

Fig. 2.1

(a) One of the conditions required for the formation of a well-defined interference pattern is that the two sources are coherent.

State what is meant by *coherent sources* and suggest how coherence of S_1 and S_2 can be achieved in this case.

……

……

……

……[2]

(b) S_1 and S_2 are in phase. The speaker S_1 is moved slowly away from P along the line PS_1. As S_1 is moved, the sound detected at P fluctuates in intensity.

Explain this observation.

……

……

……

……[2]

(c) In moving the source from S_1 to point X as shown in Fig. 2.1, the intensity of the sound at P changes from a maximum to a minimum. The distance $S_1X = 0.082$ m.

Calculate the wavelength of the sound emitted by the sources.

wavelength = …….. m [1]

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(d) S_1 remains at the point X and the frequency f of the sound emitted from both S_1 and S_2 is gradually increased until a maximum sound intensity is first detected at point P. This occurs when f = 4100 Hz.

(i) Estimate a value for the speed of sound.

speed of sound = …….. m s^{-1} [2]

(ii) Explain why the maximum sound intensity detected at P when S_1 is at point X differs from that detected at P if S_1 is at its original position (i.e. when $S_1P = S_2P$).

……

……

……

……

……

……..[1]

(e) S_1 has an intensity of I and S_2 has an intensity of 3 I. Determine the intensity at point P in terms of I when S_1 is at its original position.

intensity = …… I [3]

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3 (a) Define *electric field strength.*

……

……[1]

(b) Time-of-flight mass spectroscopy uses the arrangement shown in Fig. 3.1 to measure the mass of molecules. A laser pulse knocks an electron out of a molecule in a sample placed midway between the parallel charged plates, leaving it as a positively charged ion. The positively charged ion accelerates towards the detector due to the presence of an E-field as shown in Fig. 3.1.

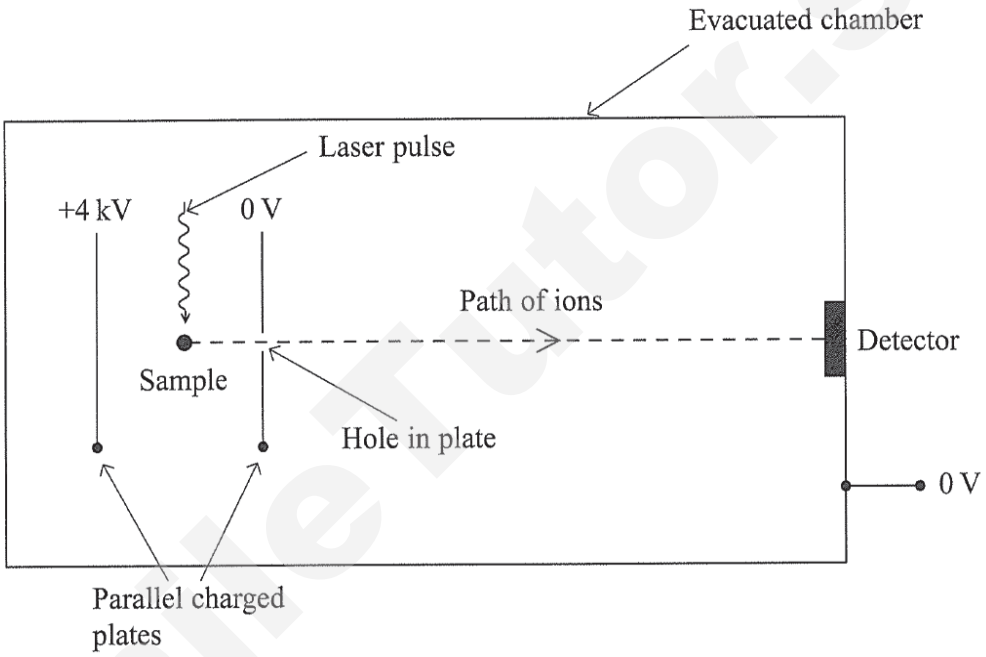

Fig. 3.1

(i) Draw the electric field lines between the two plates in Fig. 3.1. [1]

(ii) The parallel charged plates are placed 5.00 cm apart. Determine the electric field strength, *E* at the centre of the parallel charged plates.

electric field strength = …….. V m^{-1} [1]

(iii) State the amount of charge on each of the ion created.

charge = …….. C [1]

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(iv) Show that the speed, *v*, of a positively charged ion as it reaches the hole in the plate is given by

$$v = \sqrt{\frac{6.4 \times 10^{-16}}{m}} \ ,$$

where *m* is the mass of the ion in kg. It can be assumed that the ions were at rest initially.

[2]

(v) The distance between the hole in the plate and the detector is 1.5 m. The time taken for an ion to cover this distance is 2.3 μs. Calculate the mass of this ion.

mass of ion = …… kg [2]

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4 A student had a lamp rated at 3.0 V, 0.20 A. He had only a battery of 12 V with negligible internal resistance. In order to obtain a voltage of about 3.0 V, he connected a circuit as shown in Fig. 4.1. He used a voltmeter to check the voltage before connecting the lamp between terminals A and B. The resistance wire CD has a length of 1 m and a total resistance of 1000 Ω.

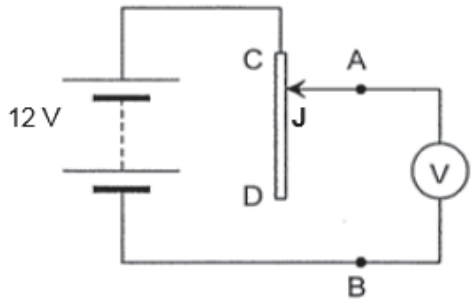

Fig. 4.1

When the sliding contact J was moved from C to D in Fig 4.1, the voltmeter reading fell from 12 V to 11 V.

(a) Show that the resistance of the voltmeter is 11.0 kΩ.

[2]

(b) The student then modified the circuit to that shown in Fig. 4.2. He is now able to adjust the sliding contact J to obtain a voltmeter reading of 3.0 V.

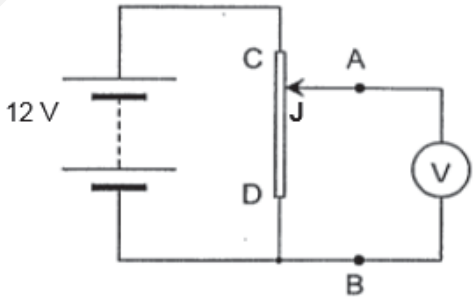

Fig. 4.2

(i) Calculate the current flowing through the voltmeter when it gives a reading of 3.0 V.

current = …….. A [1]

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(ii) Assuming this current is negligible compared with the current flowing through the resistance wire, determine the distance from C that the sliding contact J would be at.

distance from C = …… m [1]

(iii) Calculate the power dissipated in the resistance wire length CJ calculated in **(b)(ii)**.

power = …… W [2]

(c) The student then replaced the voltmeter with the lamp across AB. Explain why the lamp did not light up assuming the lamp is not defective.

……

……

……

……[2]

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5 A simple transformer with an iron core is illustrated in Fig. 5.1.

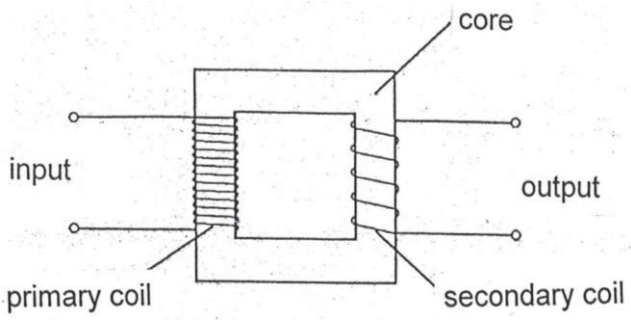

Fig. 5.1

(a) Explain how the transformer works.

……

……

……

……

……

……[3]

(b) A transformer has 500 turns in the primary coil and 10 turns in the secondary coil. The root-mean-square (r.m.s.) value of the alternating voltage and current in the primary coil are 240 V and 2.0 A respectively.

(i) Explain what is meant by the root-mean-square (r.m.s.) value of an alternating current.

……

……[1]

(ii) Determine the r.m.s. values of the voltage and current in the secondary coil. State an assumption made.

voltage in the secondary coil = …….…….. V [1]

current in the secondary coil = ……A [1]

Assumption:

……

……[1]

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6 Parachutes have been used by the military for various purposes. The material for the parachute changed from silk to nylon since World War 2. Most armies operate parachute troops for one role or another. In this context, the term *rate of descent* refers to the terminal velocity achieved by the paratrooper during an operation. The recommended rate of descent for a paratrooper is 5.8 m $s^{-1.}$

There are two basic types of jumps from an aircraft: *LALO* (Low Altitude Low Opening) and *HALO* (High Altitude Low Opening).

LALO Operation

In a *LALO* Operation, a large number of troops is dropped into an area quickly and they spend little time in the air. A large Drop Zone (DZ) is usually required for such operation. For mass combat drops, troops are normally dropped below 300 m. The disadvantage is that the low flying aircraft are much more vulnerable to anti-aircraft fire. Modern parachutes specially designed for low altitude jumps can allow jumps at the extremely low altitude of 76 m.

HALO Operation

HALO is most commonly used by troopers for covert operations behind enemy lines. The high altitude - usually above 8200m - is well above the visual and auditory range of enemy ground troops and also at a safe distance from most anti-aircraft fire. The disadvantage of *HALO* jump is that the high altitude requires special equipment due to the environmental pressure and temperatures. The troopers have to bring oxygen above 4250 m, respirators and protective clothing in order to survive. The advantage is that the paratroopers should be able to land on smaller Drop Zones (DZs).

Fig 6.1 presents the two types of parachutes (MC1 and MC6) used by US Army.

Parachute Model	**MC1**	**MC6**
Effective area of parachute	90.0 m^2	75.4 m^2
Length of suspension line	6.7 m	6.5 m
Tensile strength of line	1780 N	1780 N
Time for 360° turn	9 second	5 second
Assembled weight	13 kg	13 kg
Minimum exit altitude	152 m	152 m
Maximum exit velocity (1 Knot = 1.85 km h^{-1})	150 Knots	150 Knots

Fig. 6.1

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Fig. 6.2 shows the descent rate and exit weight data from test drops of the 2 parachutes at different heights. (Sea level refers to altitude very close to the Earth's surface.)

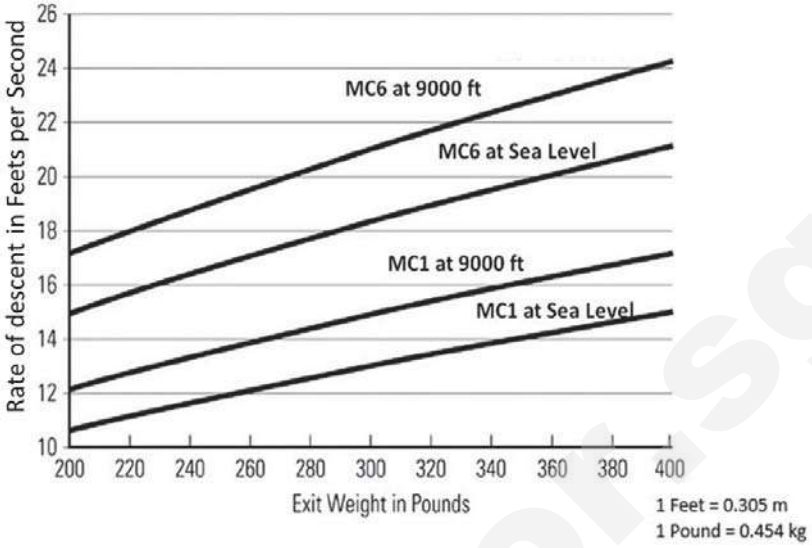

Fig 6.2

(a) Suggest a reason why nylon is a better choice of material for parachute as compared to silk.

……

……[1]

(b) Draw a clearly labelled free body diagram of a trooper when his parachute opens fully during a jump. [1]

(c) With reference to Fig 6.1, state and suggest a reason which parachute gives a higher rate of descent?

……

……

……

……

……[2]

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(d) Suggest a suitable reason why the same parachute will produce two different rate of descent as shown in Fig. 6.2?

……

…….[1]

(e) The formula for air drag is $F_{drag} = ½ \rho C_D A v^2$, where ρ is the density of the air, C_D is the drag coefficient, A is the effective area of the parachute and v is the velocity of the paratrooper.

Experiments were carried with one of the parachute from Fig. 6.1 to determine the relationship between the air drag and velocity of the jumper. The data obtained from the experiment is plotted into a graph as shown in Fig. 6.3.

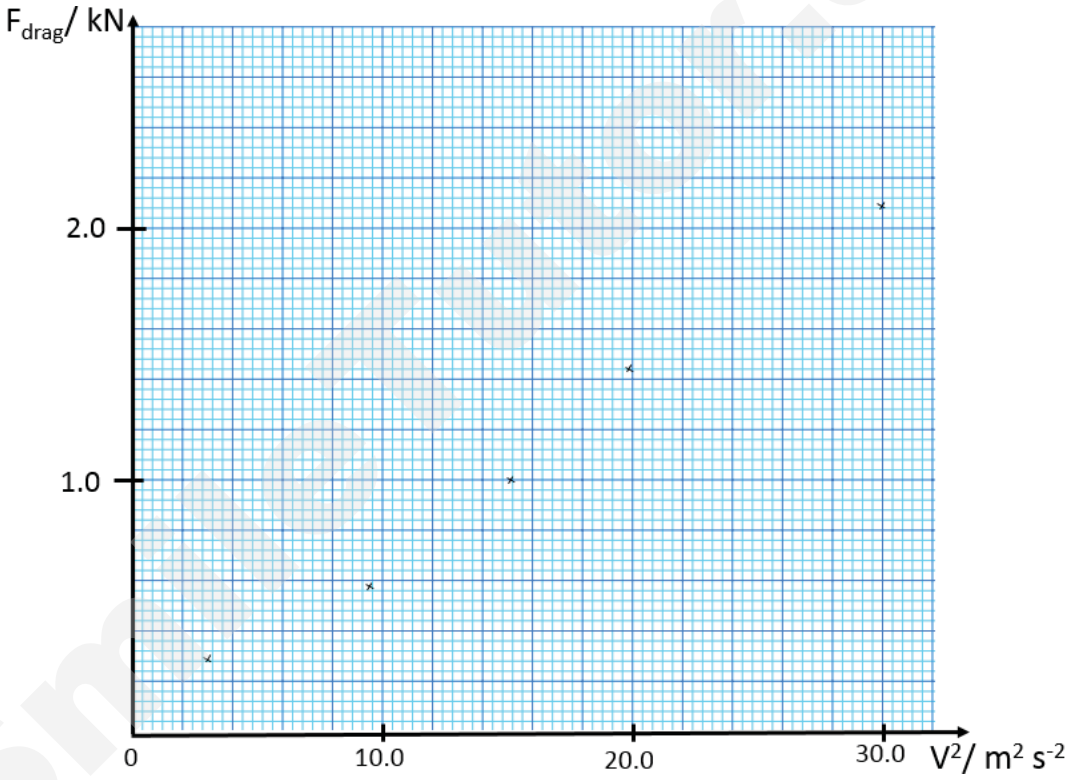

Fig. 6.3

(i) Draw the line of best fit using the data points provided in Fig. 6.3. [2]

(ii) Determine the drag force that acts on the trooper when his speed is 4.0 m s^{-1}.

drag force = …… N [1]

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(iii) Given that the density of air, ρ is 1.23 kg m^{-3} and drag coefficient, C_D of parachute is 1.50, determine the effective area of the parachute.

effective area = …… m^2 [3]

(iv) State the model of parachute used for this experiment.

parachute model = …….. [1]

(f) **(i)** In a mission, a helicopter hovers at a fixed position above a target. Determine the speed of a paratrooper who falls for 2 seconds after dropping out of the helicopter. (Assume air resistance is negligible during the fall)

speed = …… m s^{-1} [1]

(ii) Using the answer from **(i)**, sketch the velocity-time graph of the trooper from the moment he made the jump until he reaches terminal velocity. You may assume that the parachute opened two seconds after he made the jump and the terminal velocity is 5.8 m s^{-1}. [2]

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Section B (12 Marks)

It is recommended that you spend about 30 minutes on this section.

7 A blowgun is a simple weapon consisting of a narrow, long tube for firing light darts. The weapon is used by inserting the dart into the pipe of the blowgun and using the force created by the user's breath to give the projectile momentum. Its propulsive power is limited by the user's respiratory muscles.

When an absorbent material is placed some distance from the blowgun, the darts fired from the blowgun are observed to create a hole with diameter of 10 mm and penetrate a depth of one to two centimeters.

Design a laboratory experiment to investigate how the depth of penetration varies with the speed of the dart. In your account you should pay particular attention to

a) how the speed of the dart may be measured,

b) how the depth of penetration of the dart into the absorbent material is to be measured,

c) how the speed of the dart is to be changed,

d) the analysis of the data,

e) the precautions to be taken to improve the safety of the experiment.

You may assume that all of the following equipment is available, together with any other standard laboratory apparatus that would be found in a school science laboratory.

Blowgun	Measuring Tape
Darts	Air Pump
Stopwatch	Sheets of absorbent material (cork)
Photogates	Aluminium foils
Metrerule	Microphone
Vernier Calipers	Video Camera
A pail of water	Cathode Ray Oscillocope

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DIAGRAM

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Class Adm No

Candidate Name: _____

H

millennia institute

2017 Preliminary Examination II
Pre-university 3

H2 Physics **9646/03**
Paper 3 Longer Structured Questions

Wednesday **13 Sep 2016** **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and admission number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, and glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 8
2	/ 10
3	/ 10
4	/ 12
Sect B	
5	/ 20
6	/ 20
7	/ 20
Total	

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section

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1 Two stars with masses M_1 and M_2 are separated by a distance R of 1.2×10^{10} m as shown in Fig.1.1.

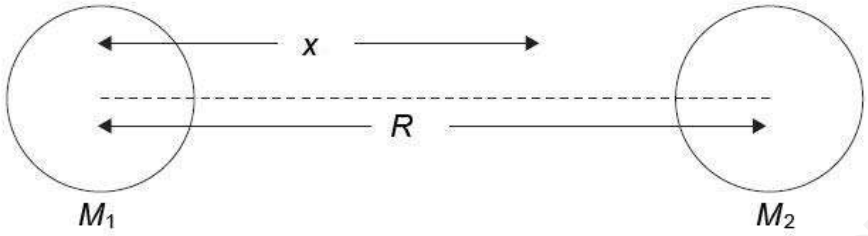

Fig. 1.1

The total gravitational potential due to the stars at any point along a line joining their centres is V. The graph in Fig. 1.2 shows how V varies with the distance x from the centre of star M_1.

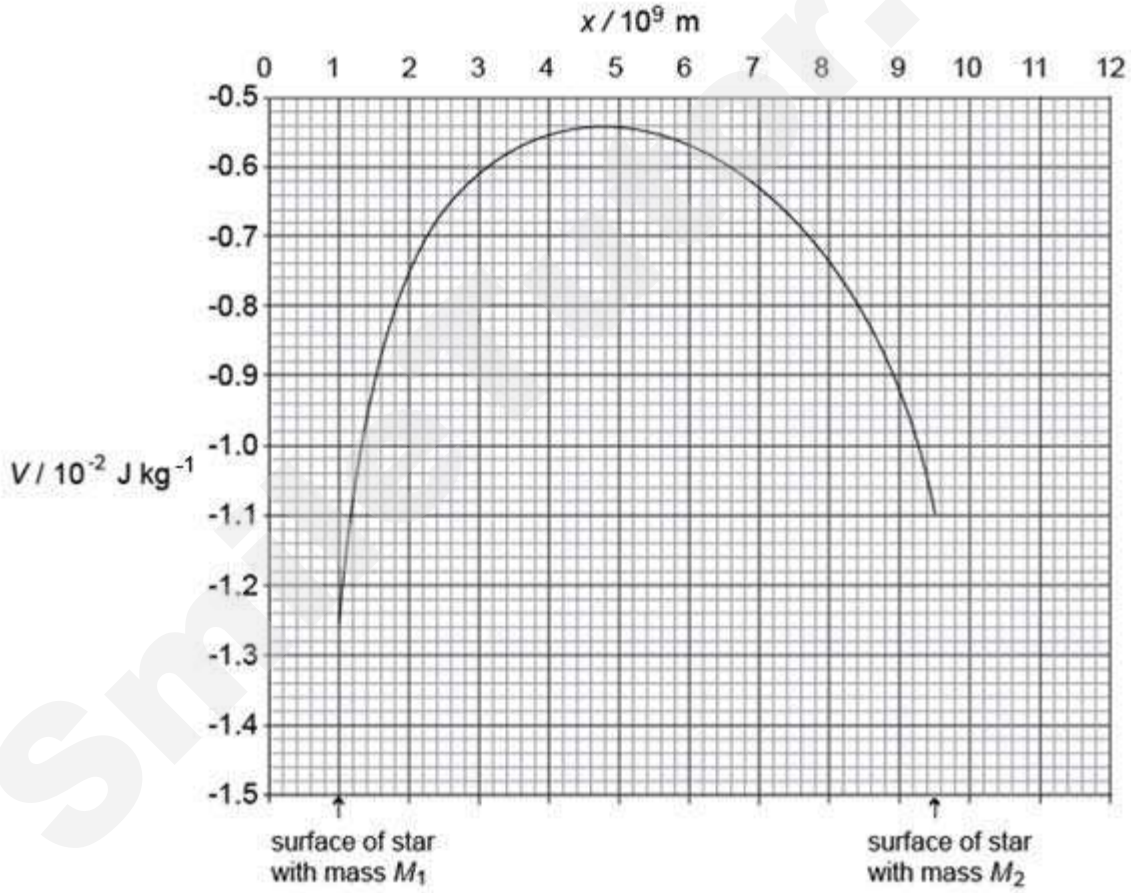

Fig. 1.2

A particle is launched with kinetic energy E_K from the surface of star with mass M_1.

The particle arrives at the surface of the star of mass M_2.

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(a) **(i)** Explain what is meant by the term *gravitational potential*.

……

…… [1]

(ii) Explain why all values of gravitational potential are negative.

……

…… [1]

(b) Use the graph to explain whether the kinetic energy of the particle when it arrives at the surface of M_2 is less than, equal to, or larger than its initial kinetic energy E_K.

……

……

……

……

…… [2]

(c) Determine the distance x from the centre of star M_1 at which the gravitational field strength due to the two stars is zero. Show clear explanation of how you arrive at the answer.

distance x = …….. m [2]

(d) Determine the ratio $\frac{M_1}{M_2}$.

ratio = …….. [2]

[Turn over

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2 A heat pump is a device that extracts heat from one place and transfers it to another. Refrigerators and air conditioners are both common examples of this technology. Heat pumps work by changing the state of a refrigerant gas through a cycle of evaporation and condensation.

Fig 2.1 shows that in a heat pump, a compressor pumps the refrigerant between two heat exchanger coils.

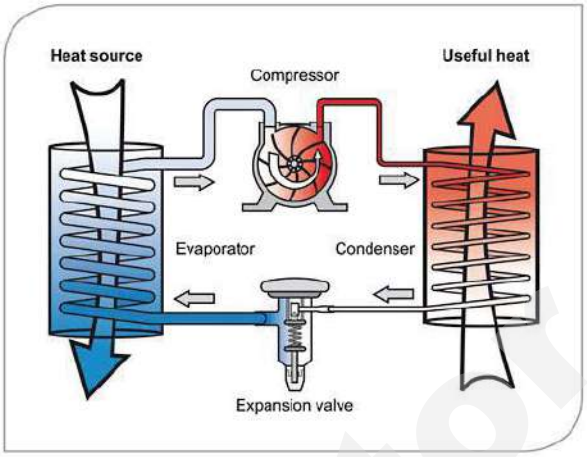

Fig. 2.1

In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed as it moves to the other coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle. The heat pump cycle is fully reversible by reversing the direction of movement of the refrigerant. Thus heat pumps can provide year-round climate control – heating in winter and cooling in summer

In a particular heat pump, a fixed mass of gas undergoes a cycle of changes in pressure, volume and temperature as illustrated in Fig. 2.2. Between **A** and **B**, the gas absorbs heat from the atmosphere (gas heats up), and between **C** and **D** it delivers heat to the inside of a building (gas cools down).

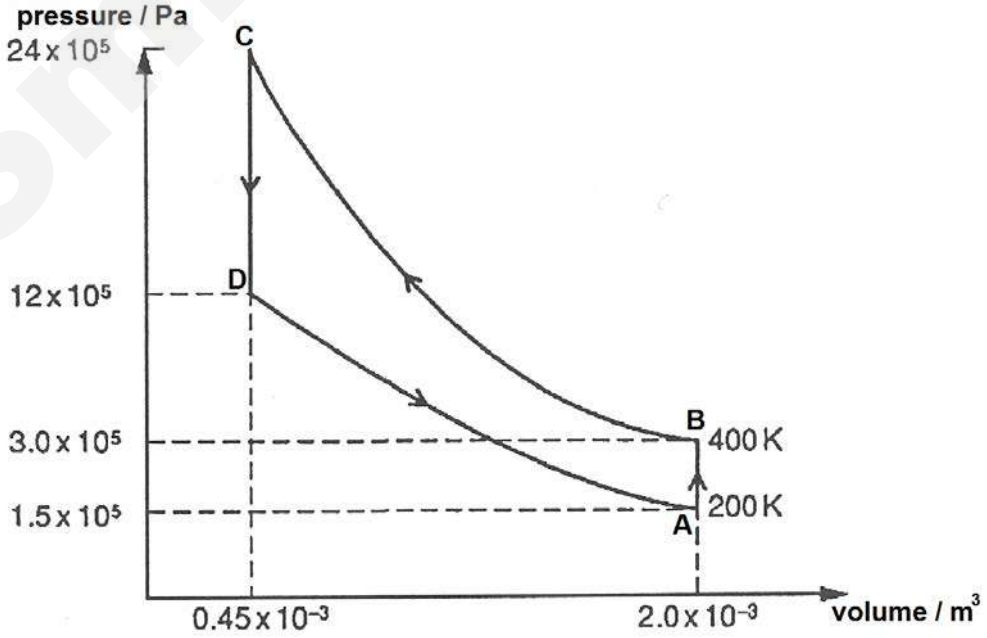

Fig. 2.2

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(a) The table below shows the increase in internal energy which takes place during each of the changes **A** to **B**, **B** to **C** and **C** to **D**. It also shows that in both of sections **B** to **C** and **D** to **A**, no heat is supplied to the gas.

	increase in internal energy / J	heat supplied to gas / J	work done on gas /J
A to **B**			
B to **C**	1200	0	
C to **D**	-1350		
D to **A**	-600	0	

Fig. 2.3

(i) Using the first law of thermodynamics and necessary data from the graph, complete the table in Fig 2.3. You will find it helpful to proceed in the following order:

1. work done on gas
2. heat supplied to gas for **C** to **D**
3. increase in internal energy **A** to **B**
4. heat supplied to gas for **A** to **B** [4]

(ii) **1.** With reference to values in Fig 2.3, and given that the cycle is completed 20 times per second, show that the minimum average power of the motor required to run the pump is 12 000 W.

[2]

2. Determine the average rate of supply of heat by the gas to the building.

rate of supply of heat = …….. W [1]

(b) Given that the gas can be assumed to be ideal, determine the change in temperature in the process **C** to **D**.

change in temperature = …….. K [3]

[Turn over

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3 **(a)** State the laws of electromagnetic induction.

……

……

……

……

……

…… [4]

(b) Fig. 3.1 shows a circular coil of wire placed in a uniform magnetic field of flux density 5.0×10^{-5} T. The coil has 400 turns, a resistance of 4.0 Ω and an area of 25 cm^2.

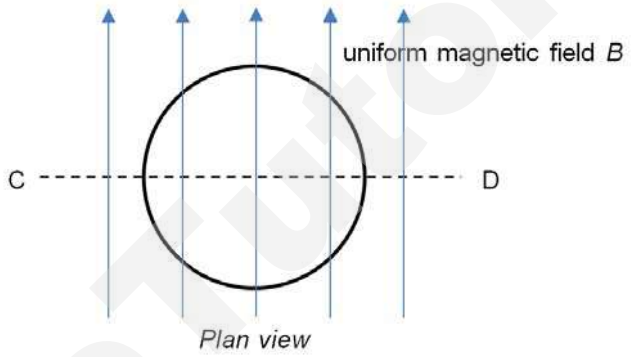

Fig. 3.1

The coil rotates about the axis CD at constant angular velocity.

(i) Using the axes in Fig. 3.2, sketch the following graphs, starting from when the coil is in the position as shown in Fig 3.1. No values need to be shown on either axes.

1. Variation of the magnetic flux linkage with time for one complete cycle. Label this graph as B. [2]
2. Variation of the induced e.m.f. with time for one complete cycle. Label this graph as E. [2]

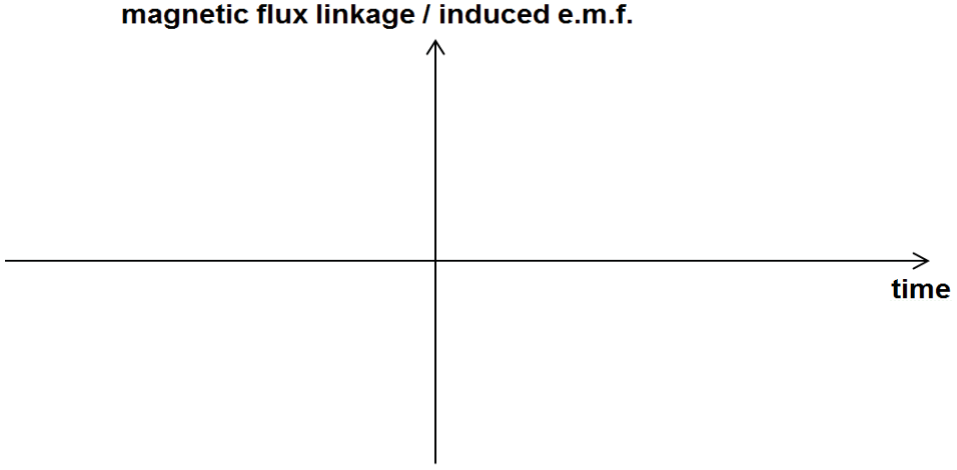

Fig. 3.2

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(ii) Determine the amplitude of the induced e.m.f. when the coil is rotating at a constant angular velocity of 18.0 rad s^{-1}.

e.m.f. = …….. V [2]

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4 **(a)** What is meant by *mass defect* of a nucleus?

……

…… [1]

(b) The Singapore one-cent coin has a mass of 3.0 g. Assuming that it is made entirely of $^{64}_{29}Cu$ atoms, calculate the energy that would be required to separate all the neutrons and protons in the coin. The following data is given:

rest mass of $^{64}_{29}Cu$ nucleus = 63.92976 *u*
rest mass of neutron = 1.00867 *u*
rest mass of proton = 1.00728 *u*
You may ignore the rest mass of the electron.

energy required = …….. J [5]

(c) A recent theory suggests that the proton may be unstable with a half-life of the order of 10^{34} years. After how many years would 1% of the 3×10^{33} protons in a swimming pool be expected to decay?

number of years = …….. [3]

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(d) In a particle detector, such as a cloud chamber, particles leave tracks which can be photographed. One such photograph is sketched in Fig. 4.1. The sketch shows a series of events started by the particle responsible for track A. Tracks D and E were not visible in the original photograph but have been added to the sketch. Such tracks were always straight. Other tracks are curved due to a uniform magnetic field acting at right angles to the plane of the sketch. All the tracks are in the plane of the sketch.

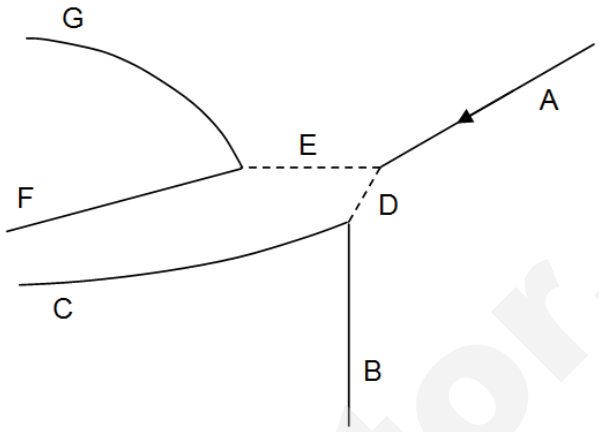

Fig. 4.1

State and explain what can be deduced from each of the following observations:

(i) Tracks D and E are straight.

……

…… [1]

(i) Track C appears to be more curved than track B.

……

…… [1]

(iii) Tracks B and C curve in opposite directions.

……

…… [1]

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Section B

Answer **two** questions in this section

5 In this question, all effects of air resistance may be neglected.
A firework of mass m is launched with an initial velocity of magnitude v at an angle of 60° to the ground, which is horizontal.

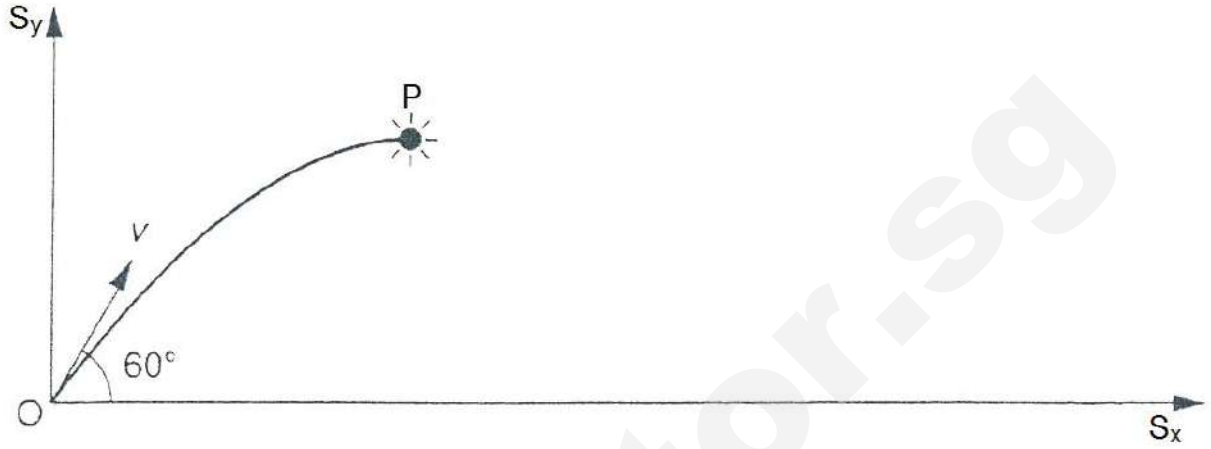

Fig. 6.1

Fig 6.1 shows the path of the firework from the point of projection O to the point of maximum height, P. At the instant when the firework is at P, it explodes and separates into two parts, A and B. The mass of A is $\frac{2}{3}m$, and the mass of B is $\frac{1}{3}m$. Immediately after the explosion, part A is momentarily at rest, and part B moves horizontally. Parts A and B then move along different paths, but strike the ground at exactly the same time.

(a) **(i)** Show that expressions for the magnitudes of the following are both $\frac{1}{2}mv$.

1. Momentum of the firework immediately *before* the explosion:

[2]

2. Momentum of part B immediately *after* the explosion:

[2]

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(ii) By determining the velocity of part B immediately after the explosion, deduce an expression for the additional kinetic energy supplied to parts A and B by the explosion.

kinetic energy = …….. J [4]

(b) On Fig 6.1, sketch the paths followed by parts A and B after the explosion. Label these paths clearly. [2]

(c) Explain, by showing appropriate calculations, why the two parts of the firework reach the ground at the same time.

……

……

……

……

……

…… [3]

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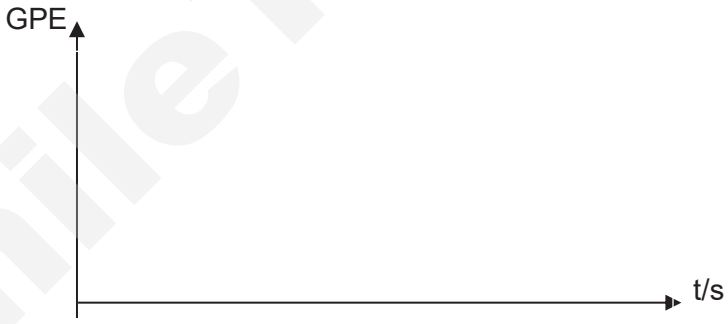
(d) The firework moves with initial velocity v of 25.0 ms^{-1} and has mass of 0.35 kg. Determine the distance between parts A and B when they strike the ground.

distance = …….. m [4]

(e) For part A, for the time starting from immediately after the explosion until it hits the ground, use the axes below, showing known values on the X-axis, sketch graphs to show

(i) how its gravitational potential energy varies with time, [2]



(ii) how its kinetic energy varies with time, [2]



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6 **(a)** Two long, straight wires are held parallel to each other, as shown in Fig. 7.1, and are connected to a circuit such that they carry current of the same magnitude, flowing in the same direction.

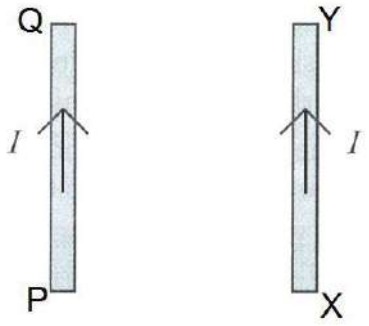

Fig. 7.1

Fig. 7.2 shows a plan view from the top end of the wires.



Fig. 7.2

(i) Draw arrows on Fig. 7.2, to show the direction of

1. the magnetic field at Q due to the current in wire XY (label as **B**), [1]

2. the force at Q as a result of the magnetic field due to the current in wire XY (label as **F**), [1]

(ii) State, by reference to an appropriate Newton's law of motion, the direction of the force on wire XY.

……

…… [2]

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(b) In an experiment, a student set up a horizontal steel wire of the same kind in **(a)**, such that it is fixed at one end and kept under tension using standard mass suspended over a pulley at the other end, as shown in Fig. 7.3.

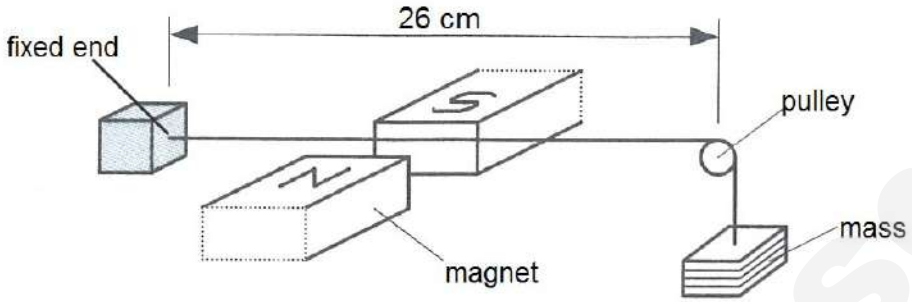

Fig. 7.3

The two ends of the wire, at the fixed point and the pulley, are connected to an low-voltage alternating supply. Poles of a magnet are placed near to the center of the horizontal section of the wire, producing a magnetic field that is at right angles to the wire.

By changing the amount of suspended mass, the tension in the wire can be varied, thereby changing the speed at which waves may travel along the wire. With the alternating supply switched on, the student noticed that when the suspended mass is increased gradually, starting from a small value, the amplitude of vibration of the wire would increase to a maximum and becomes smaller when more mass is added.

(i) Explain

1. why the wire vibrates,

……

……

……

……

……

…… [3]

2. Why, at one value of the tension, the amplitude of vibration is a maximum.

……

……

……

……

……

…… [3]

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(ii) The distance between the fixed point and the pulley is 26 cm.

1. draw a sketch to illustrate the shape of the stationary wave on the wire, [1]

2. determine the wavelength of this stationary wave.

wavelength = …….. m [1]

(iii) It is known that speed of propagation v of a wave on a string depends on tension T in the string and linear density μ (mass per unit length), by the equation

$$v = \sqrt{\frac{T}{\mu}} \ .$$

The wire has a mass of 12 g and total length of 1.00 m, and it first vibrates with maximum amplitude when the mass is 800 g.

Determine frequency of vibration of the wire.

frequency = …….. Hz [4]

(iv) Outline briefly the use of a stroboscope as an alternative experimental method with which the frequency of vibration of the wire at this mode of vibration can be verified.

……

……

…… [1]

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(c) At a distance d from a long straight wire carrying a current I, the magnetic flux density B is given by

$$B = 2.0 \times 10^{-7} \times \frac{I}{d}$$

By using the expression given above, and by making **reasonable estimates** of the magnitudes of the quantities involved, explain why any two wires carrying alternating current are not seen to vibrate under normal circumstances.

.....

.....

.....

.....

.....

..... [3]

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7 **(a)** Ruby is a crystal of aluminium oxide (Al_2O_3) in which some aluminium ions are replaced by chromium ions. It contains 0.05% to 0.5% of chromium and its colour is pink. It is the energy levels of chromium, which takes part in lasing action to produce the distinct red colour laser light in the ruby laser.

Fig 7.1 below shows the energy level diagram of chromium. The energy values shown are relative to the ground state, E_1, which is taken to be 0 eV.

Flashes of light (optical pumping) are used to achieve population inversion in the lasing medium. During this process, electromagnetic radiation of wavelength 550 nm is used to excite chromium atoms from E_1 to E_3.

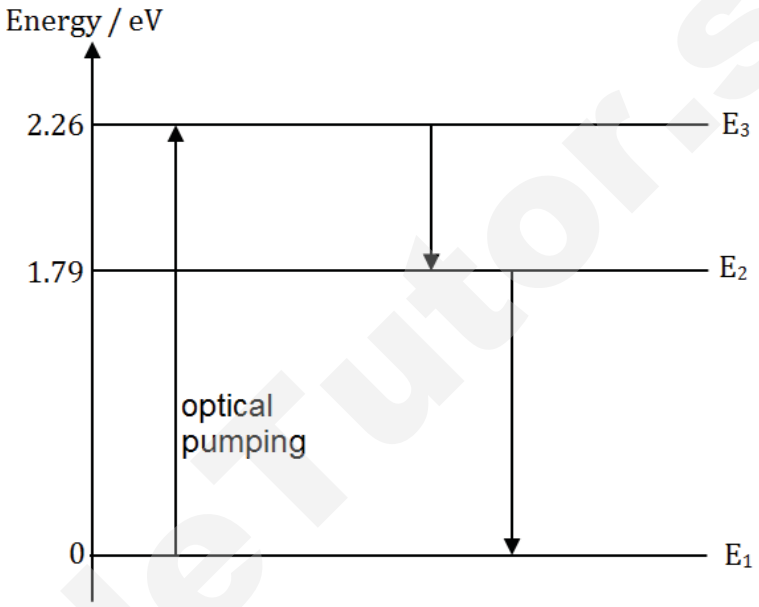

Fig. 7.1

(i) Stimulated emission and spontaneous emission are two processes in which photon emissions can take place.

Explain the main difference between how these processes **can** happen.

.....

..... [1]

(ii) Explain what is meant by *population inversion* and why it is an essential condition in laser production.

.....

.....

.....

..... [2]

[Turn over

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(iii) **1.** By estimating a suitable value of wavelength for the laser and using suitable calculations, determine the lasing transition.

lasing transition: …….. [3]

2. Hence determine the exact wavelength of the laser.

wavelength = …….. m [1]

(b) A student uses the ruby laser in **(a)** in the setup shown in Fig. 7.2 below. In the setup, two metal electrodes A and B are sealed into an evacuated glass envelope and a potential difference V, measured using the voltmeter, is applied between them.

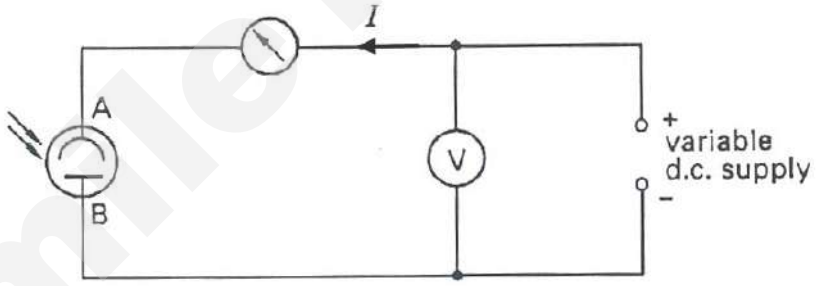

Fig 7.2

Electrode B is then illuminated with the ruby laser and I, current in the circuit, is measured for various values of V. The results are shown in Fig. 7.3.

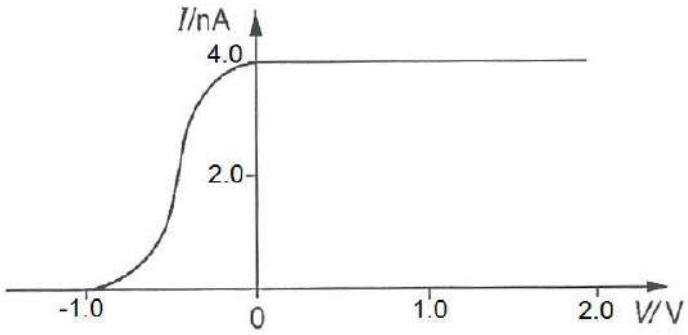

Fig 7.3

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(i) **1.** Explain briefly why current I flows in the circuit when Electrode B is illuminated with the ruby laser.

……

……

……

…… [2]

2. One observation made in this experiment is that below a certain frequency of irradiation, there will not be any current obtained. Explain the significance of this observation.

……

……

……

…… [2]

(ii) From **Fig 7.3**, deduce

1. the maximum kinetic energy of the photoelectrons that move from electrode B to A

maximum kinetic energy = ……... J [1]

2. the work function energy for the electrode B.

work function = ……... J [2]

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(iii) The average intensity of the ruby laser is 10.0×10^3 Wm^{-2}. The area of electrode B is 3.0 cm^2.

1. Estimate the number of photons incident per second on the irradiated surface.

number of photons incident per second = ... [2]

2. The current recorded on the ammeter is 2.5 μA.

Determine the number of electrons emitted per second from surface B.

number of electrons emitted per second = ... [2]

3. Hence determine the yield ratio

$$\frac{\text{number of electrons emitted per second}}{\text{number of photons incident per second}}$$

ratio = ... [1]

4. Comment on your answer to **(iii) 3.**

.....

.....

..... [1]

END OF PAPER

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Pre-university 3

H2 Physics

9646 / 01

Mark Scheme

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1. B	11. A	21. D	31. B
2. B	12. A	22. D	32. A
3. C	13. D	23. C	33. B
4. C	14. A	24. B	34. C
5. C	15. C	25. A	35. D
6. A	16. B	26. C	36. B
7. A	17. B	27. A	37. A
8. D	18. A	28. C	38. D
9. C	19. C	29. A	39. C
10. B	20. B	30. D	40. D

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Paper 1 suggested solutions		
1.	**B**	General Knowledge
2.	**B**	Using Q = I.t Q = 12 $\frac{\Delta Q}{Q} = \frac{\Delta I}{I} + \frac{\Delta t}{t}$ $\frac{\Delta Q}{Q} = \frac{0.05}{2} + \frac{0.01}{6} = 0.02667 = 2.7\%$
3.	**C**	t = time taken for 1st chestnut to fall through 12 m, from rest t_1 = time taken for 1st chestnut to fall through first 2.0 m t_2 = time taken for 1st chestnut to fall through last 10.0 m = time taken for 2nd chestnut to fall through 12 m 12.0 = ½ (9.81) t^2 → t = 1.564 s 2.0 = ½ (9.81) t_1^2 → t_1 = 0.6386 s $t_2 = t - t_1$ = 0.9254 s Let u be the initial speed of 2nd chestnut. 12.0 = u (0.9254) + ½ (9.81)(0.9254)^2 → u = 8.415 m s^{-1}
4.	**C**	At U-turn, there should be change of sign for velocity => a straight line that cuts into opp-sign region a is gradient of v-t graph and should be same throughout. Same sign for acceleration as decelerate when v and a opp sign at first, then accelerate when v and a becomes same sign after U-turn.
5.	**C**	Area under F-t graph = Change in momentum Area = (6)(x/3) + ½ (4)(2/3 x) = 20 units X = 6

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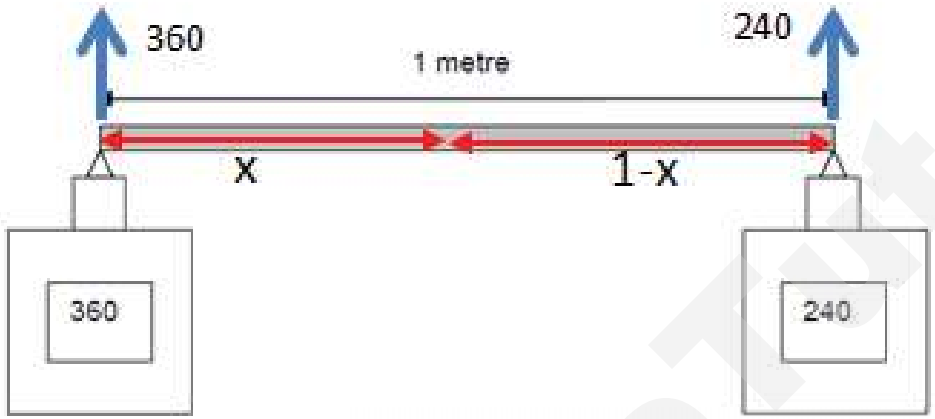
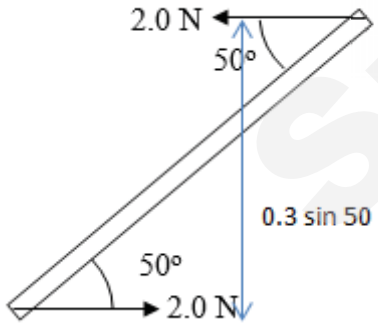
6.	**A**	From the first diagram, it can be deduced that block Z is rougher than block X. When block Z is in contact with the table surface, it requires a smaller force to keep the blocks at constant velocity compared to when block Y is in contact with the table. So, Y is rougher than Z. Hence, the order of decreasing roughness is YZX.
7.	**A**	 360 x X = (1-X) x 240 X = 0.4 m Hence it is 0.1 m to the left.
8.	**D**	

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9.	**C**	Work Done = F.S cos θ = 2500 x 15 cos 30 = 32476 J = 32500 J
10.	**B**	Ep = mgh = 4.2 x 9.81 x 0.29 = 11.94 J = 12J (2 SF) Since the mass is lower than original position, the gain is Ep is negative. Hence Ep = -12 J F = kx (Using Hooke's Law) 4.2 x 9.81 = k (0.29) K = 142 Es = ½ k x^2 = ½ (142)(.29)^2 = 5.97 J = 6.0J (Positive)
11.	**A**	Direction of velocity is changing. Hence it is not the same.
12.	**A**	Tension is minimum at the top. Fnet = $m r \omega^2 = T + mg$ $T = m (r \omega^2 - g)$
13.	**D**	$F_M = \frac{GMm}{\frac{d^2}{2}} = 4\frac{GMm}{d^2}$ to Left $F_{2M} = \frac{G(2M)m}{\frac{d^2}{2}} = 8\frac{GMm}{d^2}$ to right Net force is $\frac{4GMm}{d^2}$ to the right
14.	**A**	Consider potential at surfaces of the planets: $\phi_A = -\frac{GM}{r}$ $\phi_B = -\frac{G(8M)}{2r} = 4\phi_A$ Hence, potential at surface of planet A must be smaller in magnitude compared to the potential at surface of planet B (ie options A or B). The gravitational potential near each of the planets is mainly due to that planet and the graphs must be reciprocal curves. Alternatively – use Graphic Calculator to plot and compare

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15.	**C**	f = n $\omega = 2\pi f = 2\pi n$ rad s^{-1}
16.	**B**	KE = ½ m $\omega^2(X_0^2-X^2)$ = ½ x 0.15 x ω^2 x $(0.025^2-0.01^2)$ = 0.62 ω^2 = 15746 Since $\omega = 2\pi f$ f = 19.9 Hz = 20 Hz
17.	**B**	Heat supplied = heat absorbed Pt = mc ΔT (1000)(200) = (1.5) c (357 – 300) c = 2339 = 2400 J kg^{-1} K^{-1}
18.	**A**	the term Nm/V is total mass of gas per unit volume, thus density 2.0 x 0.3 x sin 50 = 0.460 Nm
19.	**C**	V = f λ $\omega = 2\pi f = 0.35$ f = 0.0557 λ = 0.50 / 0.0557 = 8.97 = 9.0 m (2 SF)
20.	**B**	$\Delta\phi = \frac{\Delta t}{T} \times 2\pi = \frac{1}{8} \times 2\pi = \pi/4$
21.	**D**	$finge\ sep\ x = \frac{\lambda D}{a}$ To increase x, increase wavelength.
22.	**D**	**A** is correct. **B** is correct. $n_y\lambda_y = n_v\lambda_v$ $\frac{\lambda_y}{\lambda_v} = \frac{n_v}{n_y}$ $\frac{600}{400} = \frac{n_v}{n_y} = \frac{3}{2}$

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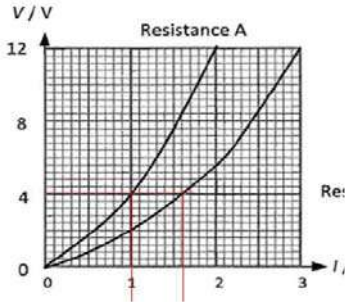
		C is correct. $n \leq \frac{d}{\lambda}$ $\leq \frac{1\times10^{-2}}{5000} \times \frac{1}{600\times10^{-9}}$ ≤ 3.33 **D** is incorrect Red light will diffract more than violet light because red light has longer wavelength than violet light.
23.	**C**	Field lines are further apart, hence the field strength is weaker.
24.	**B**	$qV = ½ mv^2$ $1.6 \times 10^{-19} \times (40 - 10) = ½ (9.11 \times 10^{-31}) v^2$ $v = 3.25 \times 10^6$ m s^{-1}
25.	**A**	V = WD/Q = 20/5 = 4
26.	**C**	 From graph, Current is 1.0 A and 1.6 A Totally current is 2.6 A.
27.	**A**	Using the potential Divider Method: Potential at Y = $2 \times \frac{5}{6} = 1.667$ Potential at X = $2 \times \frac{3}{6} = 1.0$ Hence potential difference = 0.667

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28.	**C**	6 // 8 = 3.429 Total Resistance = 3.429 + 2 = 5.429 Current = V/R = 10 / 5.429 = 1.842 A V = I R = 1.842 x 3.429 = 6.3165 I across 6 ohm = V/R = 6.3165/6 = 1.053 = 1.1 A (2 SF)
29.	**A**	According to FLHR, the force on the positive ions is DOWNwards.
30.	**D**	Knowledge of velocity selector
31.	**B**	magnetic flux Taken to be ideal case, all of the magnetic flux would be inside the soft iron ring core. All other quantities will be different due to the different dimensions or number of turns of the two coils.
32.	**A**	When rod EF is moved to the left, by Lenz's Law (or Fleming's Right hand Rule), induced current flows anticlockwise in the closed loop EFHG. Current flows from H to G. By Fleming's Left hand Rule, rod GH will experienced a magnetic force to the left, while rod EF will experience a magnetic force to the right. Rod EF will slow down while rod GH speeds up until both rods achieve the same speed to the left. At this time, the flux through EFHG remains constant, there will no longer be induced emf or current in the closed loop, the rods will continue to move leftward at a constant speed.
33.	**B**	1. Square the graph 2. Find Total Area : $1 \times 10^{-6} \times 10^{-6} + 4 \times 10^{-6} \times 2 \times 10^{-6} = 9 \times 10^{-12}$ 3. Mean: Area / Period = $9 \times 10^{-12} / 3 \times 10^{-6} = 3 \times 10^{-6}$ 4. Sq: $\sqrt{3 \times 10^{-6}} = 1.73 \times 10^{-3}$ A
34.	**C**	Increasing the angular frequency increases both the angular frequency and the maximum induced emf
35.	**D**	**D**

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		$E = \frac{1}{2}mv^2 \Rightarrow p = \sqrt{2mE}$ $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \propto \frac{1}{\sqrt{m}}$ **The fringe spacing Δx for double-slit experiment is proportional to λ, thus** $\Delta x \propto \frac{1}{\sqrt{m}}$ $\frac{(\Delta x)_{C60}}{(\Delta x)_n} = \sqrt{\frac{m_n}{m_{C60}}} = \frac{1}{\sqrt{720}}$
36.	**B**	Transmission coefficient is higher for electrons, hence higher chance to tunnel
37.	**A**	At very low temperature, no external energy to create electron-hole pair.
38.	**D**	electron-deficient impurity atoms IS Group III elements, introduces a donor energy level near to vb. At zero kelvin, so no energy for electrons to move to cb.
39.	**C**	Nuclide $^{156}_{64}Gd$ has 156 nucleons. total binding energy = (156)(1.3) = 202.8 pJ
40.	**D**	30 / 20 = 1.5 half-lives for X => new activity A = $(½)^{1.5}A_o = 0.354\ A_o$ 30 / 15 = 2 half-lives for Y => new activity A = $(½)^2\ A_o = 0.250\ A_o$ total activity of the mixture = $0.354A_o + 0.250\ A_o = 0.60\ A_o$

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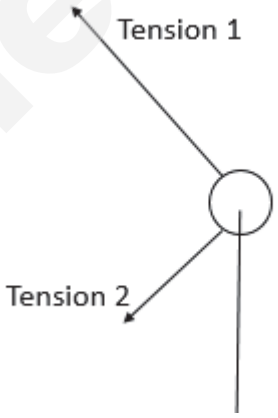
Section A

1	**(a)**		**A1**
	(b)	$\theta = \cos^{-1}(1.00 / 1.25)$ $= 36.87°$ Sum of forces along the Y Axis = 0: $T_U \cos\theta = T_L \cos\theta + mg$ (show correct substitution) $T_L = 21.0$ N (shown)	**C1** **M1** **A0**

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	(c)	$Fc = mr\omega^2$ $T_U \sin\theta + T_L \sin\theta = m(1.25 \sin\theta)\omega^2$ $\omega = 4.266$ rad s^{-1} $f = 40.7$ rev min^{-1}	**M1** **M1** **A1**
	(d)	$T_L = 0$ $T_U = mg / \cos\theta = 49.0$ N $T_U \sin\theta = m(1.25 \sin\theta)\omega^2$ $\omega = 3.13$ rad s^{-1} $f = 29.9$ rev min^{-1}	**M1** **M1** **A1**
	(e)	$T_U \sin\theta = m(1.25 \sin\theta)\omega^2$ => T_U becomes smaller $T_U \cos\theta = mg$ => $\cos\theta$ becomes bigger θ becomes smaller Alternate answer: With lower spin frequency, smaller centripetal force Fc is needed. As Fc is provided by horizontal component of Tension ($T_u \sin\theta$), which now is a smaller value required, θ becomes smaller too.	**A1** **A1** **A1** **A1**
2	**(a)**	Coherence refers to source 1 and source2 having a **constant phase difference** between each other. This can be achieved by connecting the 2 speakers to the same source	**A1** **A1**
	(b)	When S1 is moved, the **path difference** between S1 and S2 changes. When the path difference is a multiple of the wavelength, there is a constructive interference, this gives rise to a high intensity sound being produced. When the path difference is 0.5λ, 1.5 λ, 2.5 λ, a destructive interference is produced.	**A1** **A1**
	(c)	Path difference = 0.5 λ to change from a max to min 0.5 λ = 0.082 m λ = 0.164 m	**A1**

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	(d)(i)	Path difference = 0.082 λ = 0.082 f = 4100 Hz v = f λ = 336.2	**C1** **A1**
	(d)(ii)	At the original position, it is closer to the source as the intensity of the wave decreases as it is further from the source.	**A1**
	(e)	Let $I = KA^2$ Hence $K = \frac{I}{A^2}$ $A_2 = \sqrt{\frac{3I}{K}} = \sqrt{3I \times \frac{A^2}{I}} = \sqrt{3}\,A$ Summation of $A + A_2 = (1 + \sqrt{3})A = 2.732A$ $I_{new} = K(2.732A)^2$ $= \frac{I}{A^2} \times 7.464\,A^2 = 7.46\,I$	**C1** **C1** **A1**
3	**(a)**	The electric force acting per unit positive charge.	**A1**
	(b)i	Positive to negative Evenly spaced out and symmetrical	**A1**
	(b)ii	E = V/d = 4000 / 0.05 = 80000	**A1**
	(b)iii	1.6×10^{-19} C (Knocking out 1 electron)	**A1**
	(b)iv	Since it is a "**Show**" question, student must state the law of conservation of energy: Gain in KE = Work Done by the E field $\frac{1}{2}mv^2 - 0 = q\,\Delta V$ $\frac{1}{2}mv^2 = qV$ $\frac{1}{2}mV^2 = 1.6 \times 10^{-19} \times 2000$ $V = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2000}{m}} = \sqrt{\frac{6.4 \times 10^{-16}}{m}}$	**M1** **M1** (with correct substitution)
	(b)v	*Since acceleration = 0 (Outside the E Field)* *d/t = v* $\sqrt{\frac{6.4 \times 10^{-16}}{m}} = \frac{1.5}{2.3 \times 10^{-6}}$ *m = 1.50 x 10^{-27}kg*	**C1** **A1**

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4	**(a)**	Using potential Divider formula $12 \times \frac{R}{R+1000} = 11$ 12R = 11R + 11000 R = 11000 Ohm	**C1** **A1**
	(b)i	R = 11000 Ohm V = 3V I = V/R = 3/11000 = 2.73 x 10^{-4} ohm	 **A1**
	(b)ii	R/1000 x 12 = 3 R = 250 ohm (1000 – 250) / 1000 = 0.75 m	 **A1**
	(b)iii	I = V/R = 12/1000 = 0.012 A Power = $I^2R = 0.012^2$ x 750 = 0.108 W	**C1** **A1**
	(c)	When the bulb is placed parallel to AB, the effective resistance decreases as resistance of the lamp is very small compared to the voltmeter's resistance. Hence there is very little PD across AB and there is insufficient PD to light up the bulb.	**A1** **A1**
5	**(a)**	Input to the primary coil is connected to an alternating voltage and hence an AC current flows through the primary coil The ac sets up a **varying magnetic field in the iron core which links the primary coil with the secondary coil** This **changing magnetic flux linkage induces an alternating emf across each turn of the wire in the secondary coil.** According to **Faraday's law of Electromagnetic induction, the rate of change of magnetic flux linkage is directly proportional to the emf induced.**	 **A1** **A1** **A1**
	(b)(i)	It is the steady current which would dissipate heat at the same rate in a given resistor as the AC.	**A1**
	b(ii)	$\frac{V_s}{V_p} = \frac{I_p}{I_p} = \frac{N_s}{N_p}$ $\frac{V_s}{240} = \frac{2.0}{I_p} = \frac{10}{500}$ $\boldsymbol{V_s = 4.8\,V}$ $\boldsymbol{I_s = 100\,A}$ Assumption: Transformer is 100% efficient	 **A1** **A1** **A1**

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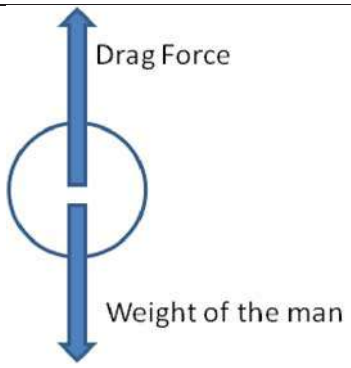
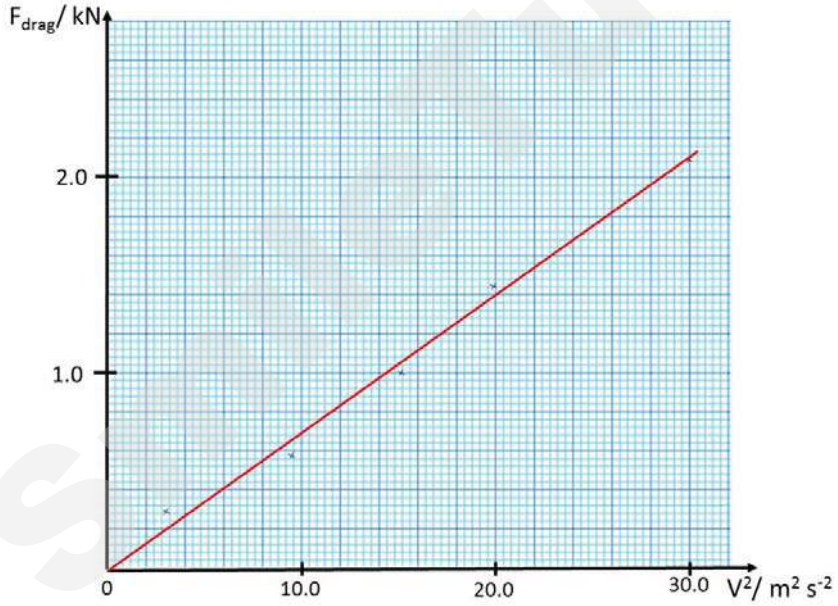
6	**a**	Light weight, Water Resistant, Good Elasticity, Cheap, Durable,	**A1**
	b		**A1** (Not looking out for magnitude)
	c	MC6 has a higher rate of descent/terminal velocity. It has a smaller effective area as compared to MC1 and hence has a smaller air resistance as compared to that arising from MC1.	**A1** **A1**
	d	The air at sea level is denser and hence will produce a larger air resistance, leading to smaller rate of descent. The air at 9000 ft is less dense and hence produced a lower air resistance.	**A1**
	e (i)		**M1 Pass through origin** **A1 line of best fit**
	(ii)	Read off from graph x = 16, Y = 1.16 kN (Answer varies according to student's graph, ECF)	**A1**
	(iii)	$F_{drag} = ½ \rho C_D A v^2$ Gradient = 1400/ 20 = 70 ½ p C_D A = gradient = 70 A = 75.88 m^2	**M1** **M1** **A1**
	(iv)	MC6 since MC6 has an area of 75.4 m^2	**A1**
	f	v = u + at v = 0 + (9.81)(2) = 19.62 m s^{-1}	**A1**

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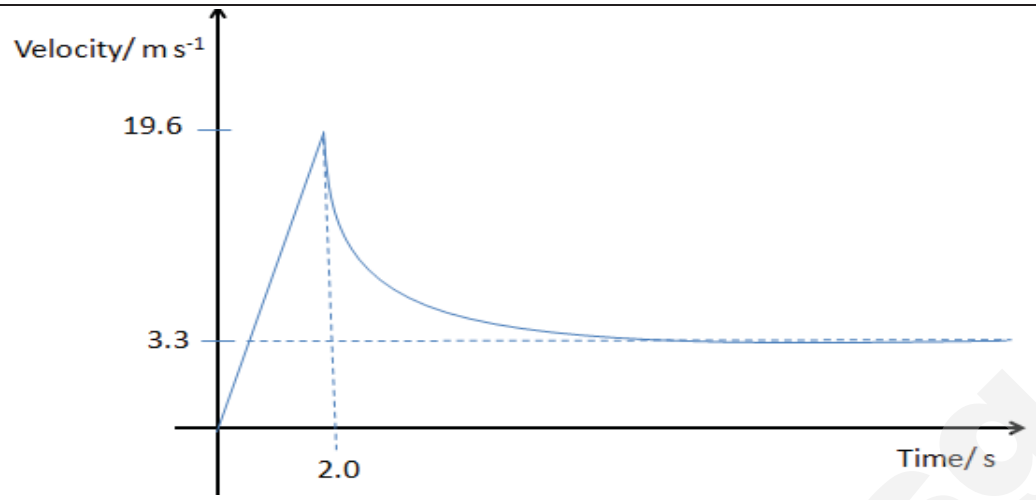
	g	 **A1** **Right Shape** **A1** **Proper annotation of important values**	
7	**Variables**	Identification of IV and DV IV = Speed of Dart v DV = Depth on target, d	**M1**
		Constant Variables Distance travelled by dart, same type of dart (Sharpness, mass), same material for absorption material	**M1**
	Diagram	Placement of photo gates and data logger Placement of pump to the blowgun to shoot the dart Placement of blowgun pointing at the target	**M1** **M1** **M1**
	Procedure	Speed of the dart measured using Photogate and datalogger Depth of penetration measured using verniar callipers (Depth measuring probe) Pump used to vary the speed of the dart	**M1** **M1** **M1**
	Analysis	Hypothesis: $d = Mv^n$ Plot a graph of lg d against lg v Gradient is n, lg M is the Y intercept	**M1** **M1**
	Safety	Stay clear of the absorption target Ensure that the blowgun is not connected to the pump	**M1**
	Accuracy	Take multiple reading of the velocity and depth and take average	**M1**

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Section A

1	(a)(i)	Gravitational potential is the work done per unit mass by an external agent to bring a mass from infinity to that point in the field.	B1
	(ii)	Gravitational potentials have negative values as the field force is attractive by nature, and so the external agent does negative work in bringing a mass into the field.	B1
	(b)(i)	Make ref to graph in recognizing that potential (or GPE) of particle **increases** from M_1 to M_2 ; therefore by **COE**, gain GPE => Loss KE and hence KE is **lesser than initial.**	M1 A1
	(c)	Field strength is zero where potential-gradient dV/dr (= g) is zero x = 4.8 x10^9 m; (allow answers in the range of 4.5 to 5.0)	M1 A1
	(d)	field strength due to M_1 = field strength due to M_2 at 4.8 x10^9 m $\frac{GM_1}{r_1^2} = \frac{GM_2}{r_2^2}$ $\frac{M_1}{4.8^2} = \frac{M_2}{7.2^2}$ $\frac{M_1}{M_2} = 0.44$ (allow answers in range 0.36 to 0.48)	C1 A1

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2 (a)(i)

	increase in internal energy / J	heat supplied to gas / J	work done on gas /J
A to **B**	**+750**	**+750**	**0**
B to **C**	1200	0	**+1200**
C to **D**	-1350	**-1350**	**0**
D to **A**	-600	0	**-600**

Max 4 marks. Minus 1 mark for each wrong answer. **A4**

(ii)1. In each cycle, net work done on gas (by pump) = +600 J **M1**

Min power to run pump = (600)(20) = 12 000 W **M1, A0**

(ii)2. In each cycle, supply of heat by the pump = 1350 J (process C to D)
Rate of heat supplied by pump = (1350)(20) = 27 000 W **A1**

(b) Using one of the processes with a known starting temp (B to C, or A to D)

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ **C1**

T_B = 720 K

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ for C to D, **C1**

$T_B = 2T_C$

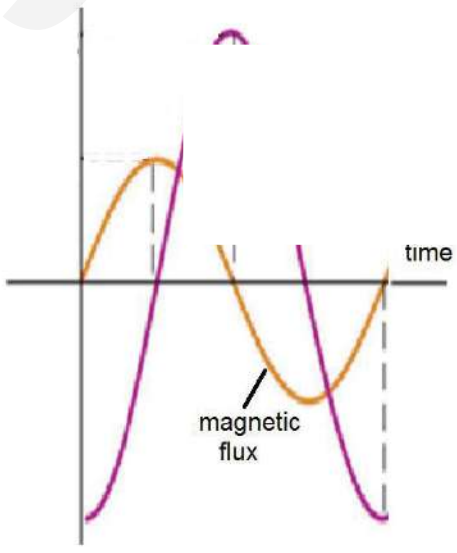
T_C = 360 K,

Thus change in temperature = 360 - 720 = - 360 K **A1**

3 (a)(i) Faraday's Law states that the magnitude of the induced emf is **directly proportional** to the **rate of change of magnetic flux linkage.** **B2**

Lenz's Law states that the **polarity of the induced emf** is such that it will produce a current that **creates a magnetic field so as to oppose** the change in magnetic flux linkage that is producing the induced emf. **B2**

(b)(i) 1. and 2.



Magnetic flux linkage graph -
Sinusoidal shape = 1 mark
Sine shape (starts from 0) = 1 mark **B2**

Induced e.m.f -
Correct shape = 1 mark
(deduct if inaccurate or kinks)

Correct phase relationship with flux linkage graph = 1 mark **B2**

* accept also set of inverted graph

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	b(ii)	$E = NBA\omega$ $E = (400)(5 \times 10^{-5})(25 \times 10^{-4})(18.0)$ $E = 9.0 \times 10^{-4}$ V	**C1** **A1**
			10
4	**(a)**	Mass defect is the **loss in mass** due to the **release of energy** in **forming the nucleus** from the individual protons and neutrons.	**B1**
	(b)	The number of Cu atoms in the 3.0 g one-cent coin, $N = \frac{M\ coin}{Molar\ Mass} \times N_A = \frac{3}{64} \times 6.02 \times 10^{23} = 2.83 \times 10^{22}\ atoms$ **C1 for division. C1 for conversion from u to kg.** For each nucleus, the binding energy is given by, $E = \left[\left(29m_p + 35m_n\right) - m_{Cu}\right]c^2$ $E = \left[(29 \times 1.00728) + (35 \times 1.00867) - 63.92976\right] \times 1.66 \times 10^{-27} \times \left(3.00 \times 10^8\right)^2$ **C1 for** $E = 8.74 \times 10^{-11}$J **finding number of nucleons. C1 for use of $E = mc^2$** Total energy involved is given by, $E_{Total} = 2.83 \times 10^{22} \times 8.74 \times 10^{-11} = 2.47 \times 10^{12}$ J	**C2** **C2** **A1**

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	(c)	1% decay => remaining N = 0.99 of No $0.99 = e^{-\lambda t}$ $T = 1.45 \times 10^{32}$ years **C1 for use of decay equation** **C1 for use of $\lambda = \ln 2/t_{1/2}$**	**C2** **A1**
	(d)(i)	Tracks D and E are straight, so the particles making these tracks are unaffected by the magnetic field and so must be electrically neutral.	**B1**
	(ii)	If both particles responsible for Track B and C have the same velocity, then the mass to charge ratio of particles in B is higher than the mass to charge ratio of particles in C. Or If both particles responsible for Track B and C have the same momentum, then the charge of particles in B is lower than the charge of particles in C. Or If both particles responsible for Track B and C have the same mass to charge ratio, then the velocity of particles in B is higher than the velocity of particles in C.	**B1**
	(iii)	Track B is the path of a charged particle that is opposite in sign to the particle responsible for track C.	**B1**
			12
5	**(a)(i)**	At highest point P , $V_x = v\cos 60° = ½ v$ $V_y = 0$ So velocity at P = ½ v Momentum $p = m(½ v) = ½ mv$	**M1** **M1** **A0**
	(ii)	By PCOM, $½ mv = 2/3\ m\ (0) + p_B$ $p_B = ½ mv$	**M1** **A0**
	(iii)	$p_B = ½ mv$ => $V_B = 3/2\ V$ initial KE before explosion = $½ m (V/2)^2 = 1/8\ mV^2$ final KE after explosion = $KE_A + KE_B$ $= 0 + ½ (1/3\ m)(3/2\ V)^2 = 3/8\ mV^2$ Additional KE = $3/8\ mV^2 - 1/8\ mV^2$ $= ¼\ mV^2$	**C1** **C1** **C1** **A1**

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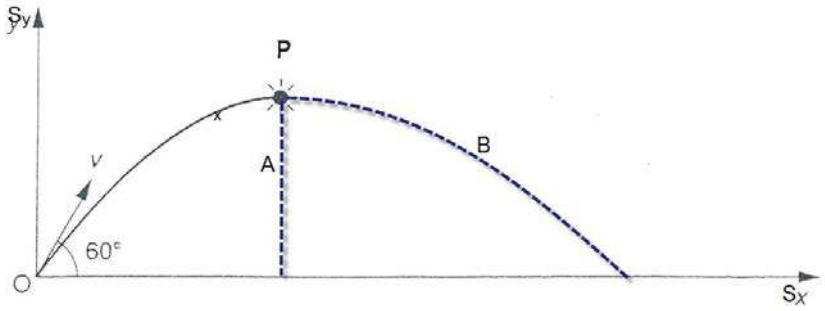
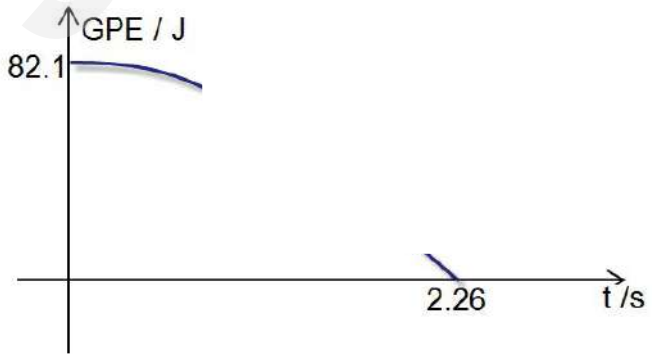
	(b)	 **B1 – A is vertically drop** **B1 – B path is longer than from O to P (higher hor velocity after explosion)**	**B2**
	(c)	At P, both A and B have same vertical velocity of 0 ms^{-1}, and both experience same downwards vertical acceleration of 9.81 ms^{-2}, and both are at same vertical height above ground. Using $s = ut + ½ at^2$ in vertical dir, $h = 0 + ½ gt^2$ $t = \sqrt{\frac{2h}{g}}$ for both A and B	**M1** **M1** **A1**
	(d)	A falls directly below P. Time to fall to ground, $t = \sqrt{\frac{2h}{g}}$ for both A and B For B, $S_x = (3/2V)(t) = \frac{3}{2}v\sqrt{\frac{2h}{g}}$ … (1) Using initial projection to find h, $V^2 = u^2 + 2as$ in vert dir, $0^2 = (V\sin 60)^2 - 2gh$ $h = \frac{3v^2}{8g} = 23.891$ m Subst h into (1), $S_x = 82.762 =$ <u>82.8 m</u>	**C1** **C1** **C1** **A1**
	(e)i	 **B1 for correct shape** **B1 for correct values on X-axis**	**B2**

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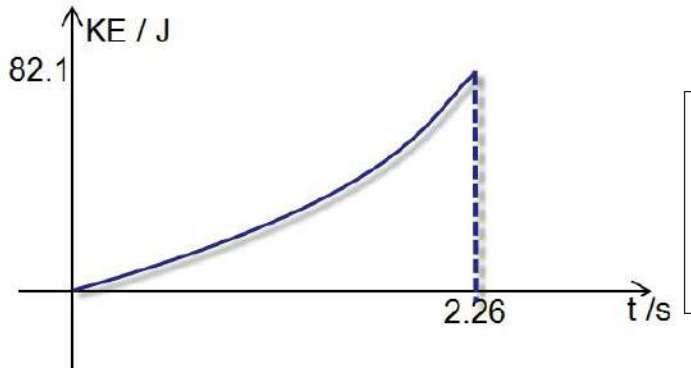
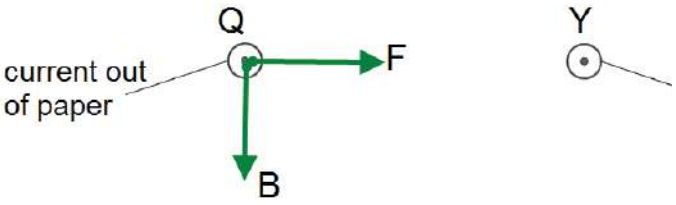
	(e)ii	 B1 for correct shape B1 for correct values on x-axis	B2
			20

6	(a)(i) 1. and 2.		B1 B1
	(a)(ii)	By **Newton's 3rd Law**, direction of force on XY is **towards left.**	B1 B1
	(b)(i)1.	When current flows in the wire, it **interacts with the magnetic field** of the permanent magnet, giving rise to a **magnetic force F** on the wire. Direction of F can be determined using **FLHR** to be either **upwards or downwards, depending on direction of current** in wire. As the a**.c. changes direction, force F changes direction** too and thus wire vibrates.	M1 M1 A1
	(b)(i)2.	**Tension of wire affects natural frequency f_o of vibration** of the wire. When tension is at a value such that **f_o coincides with frequency of the a.c. source,** **there is maximum energy transfer,** resonance occurs and amplitude of vibration becomes maximum.	M1 M1 A1
	(b)(i) 1.	Sketch to show fundamental mode - One of the lines must be dotted	A1
	(b)(i) 2.	Wavelength = 2 (26) = 0.52 m	A1
	(iii)	density μ (mass per unit length) = 0.012 kgm^{-1} T = mg = (0.8)(9.81) = 7.848 N $v = \sqrt{\frac{T}{\mu}}$ = 25.573 f = v/λ = 49.180 = 49.2 Hz	C1 C1 C1 A1

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	(iv)	Set up a stroboscope with adjustable frequency of flashing of light at right angles directly in front of the vibration wire. When frequency of flashing is same as the standing wave, the latter will appear to stand still and frequency can then be read off the stroboscope's meter.	**B1**
	(c)	Consider wires of 1 m, and large current of 10 A (fuse typically is 13A), separated by distance of 0.10 m. By F = BIL , force of 2.0 x 10^{-6} N acts on wires Estimate weight of wires of 1m around 0.10 to 0.50 N Thus magnetic force is of 5 orders smaller than weight of wire and no vibration will occur. Award 1 mark - if no estimates made, or unreasonable in most, and only stating magnetic force is too weak, or magnetic force is too small.	**Up to B2** **A1**
			20

7	**(a)(i)**	Stimulated emission is triggered by an external photon while spontaneous emission happens on its own accord.	**B1**
	(ii)	Population Inversion is when there is more number of excited atoms in the higher energy than there are in a lower energy state. It is essential condition for lasing as it ensures that the probability that an incident photon will stimulate emission exceeds the probability that the photon will be absorbed.	**B1** **B1**
	(iii)1.	As the laser light is red, a suitable estimate for the wavelength of red light is 700 nm Therefore, the energy transition involved should be about $\Delta E = hc / \lambda_{red} =$ $= \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(700\times10^{-9})(1.6\times10^{-19})}$ $= 1.78$ eV Thus likely transition is $\underline{E_2 \text{ to } E_1}$	**C1** **C1** **A1**
	(iii)2.	exact wavelength of the laser = 694 nm	**A1**
	(b)(i)1.	In photoelectric effect, atoms at the irradiated metal surface absorb photon energy and breaks free, to be ejected out. An attractive e-field between the electrodes will move these electrons across the gap and forms a current in the circuit.	**B1** **B1**

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	(b)(i)2.	By Wave model, in which energy absorption is continuous and accumulative, even with light source of low frequency, so long as sufficient time is given for energy absorption, there should be electrons ejected to form a current. The observation of presence of a threshold frequency below which no photocurrent is obtained shows up the particulate nature of light, in which energy absorption takes place in quantised manner.	**B1** **B1**
	(ii)1.	maximum kinetic energy = eVs = 1.6×10^{-19} J	**A1**
	2.	work function = hf – max KE = hc/λ - max KE = 1.2643×10^{-19} J = 1.26×10^{-19} J	**M1** **A1**
	(iii)1.	P = $(10.0 \times 10^{3})(3.0 \times 10^{-4}) = 3.0$ W Power = $\frac{N}{t}hf$ N/t of photons = 1.047×10^{19}	**M1** **A1**
	2.	$I = \frac{Q}{t} = \frac{Ne}{t}$ N/t of electrons = 1.5625×10^{13} = 1.56×10^{13}	**M1** **A1**
	3.	yield ratio = 1.49×10^{-6}	**A1**
	4.	The small yield is due to not all photons are absorbed by surface photons.	**B1**
			20

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

PHYSICS 9749/01

Paper 1 Multiple Choice **26 September 2017**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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1 A body, dropped from the edge of a cliff, is timed to take (2.0 ± 0.1) s to fall to the surface of the sea. If the acceleration of free fall is taken to be (9.8 ± 0.2) m s^{-2}, the calculated height of the cliff above the water surface should be quoted as

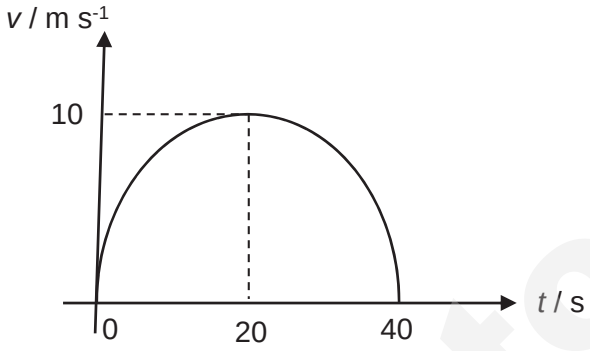
A (20 ± 0.1) m

B (20 ± 0.2) m

C (20 ± 1) m

D (20 ± 2) m

2 The velocity-time graph below depicts the motion of an object travelling in a straight line. Which of the following statements is true?



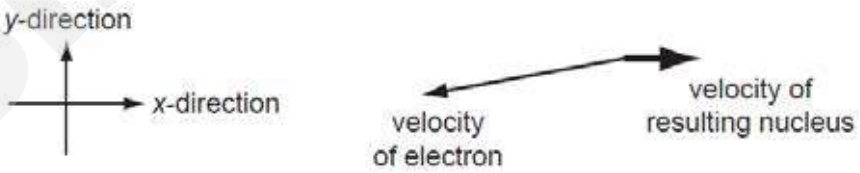
A During the first 20 s of the motion, the object accelerates and travels a distance of 200 m.

B The acceleration of the object increases during the first 20 s to become a maximum when the velocity is 10 m s^{-1}.

C The acceleration of the object when t = 5 s is equal to its acceleration when t = 35 s.

D The object decelerates during the final 20 s of its motion, with the greatest deceleration occuring at t = 40 s.

3 A stationary nucleus undergoes beta-decay. The diagram below shows the velocities of the resulting nucleus and the emitted electron.



How does the diagram support the idea that a unseen third particle is also emitted?

A If there were only two particles involved, their velocities should be equal and opposite.

B It is clear that linear momentum is not conserved in the x-direction.

C Something must carry away the extra energy.

D The linear momentum of the original nucleus has no y-component.

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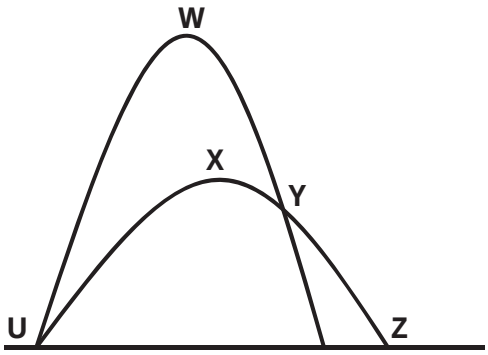
4 The paths of two identical projectiles, fired with the same initial speed but with different launch angles, are shown below. Which of the following statements is true?



A The kinetic energies of both projectiles are the same at Y if there is no air resistance.

B The potential energy of the projectile at W is lower than the potential energy of the projectile at X.

C The kinetic energy of the projectile at W and the kinetic energy of the projectile at X are both zero.

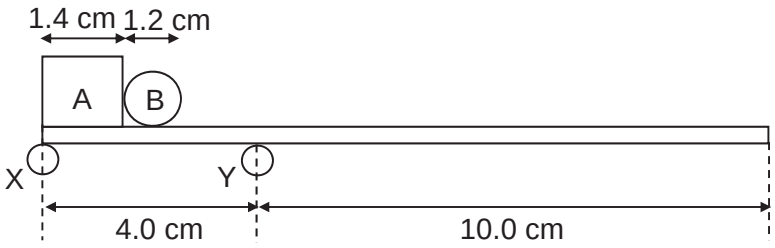
D The kinetic energy of the projectile at W is higher than the kinetic energy of the projectile at X.

5 A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One quarter of this resistance acts on the trailer. At first the acceleration of the tractor and trailer is 2.0 m s^{-2} but eventually they move at a constant speed of 6.0 m s^{-1}.

What is the force exerted on the tractor by the tow-bar when the acceleration of the tractor and trailer is 2.0 m s^{-2}?

A 1000 N **B** 3000 N **C** 5000 N **D** 8000 N

6 A beam of negligible mass is supported by two rods X and Y. Block A of mass 200 g and ball B of mass 100 g rest on the beam as shown. Both A and B have uniform density.



If ball B were to start rolling to the right, what is the distance it would have moved before the beam just loses contact with rod X? Assume that there is negligible friction.

A 6.6 cm **B** 8.0 cm **C** 8.6 cm **D** 9.4 cm

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7 A submarine descends vertically at a constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight. Which of the following relationships between the magnitudes of these three forces is correct?

A weight < drag

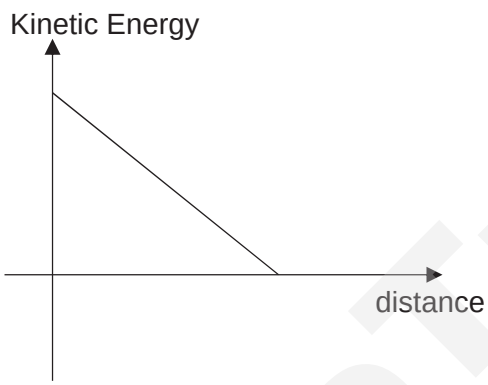
B weight = drag

C weight < upthrust

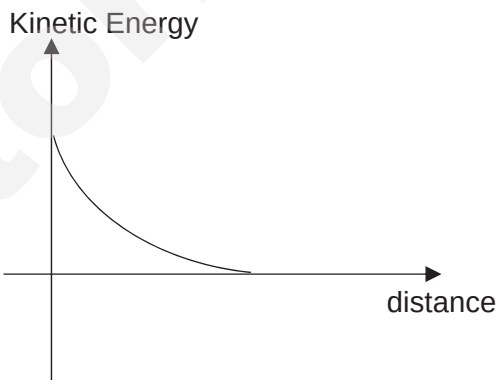
D weight > upthrust

8 A block is projected at a certain speed up a frictionless slope. Which of the following graphs correctly shows the relationship between the kinetic energy of the block and the distance travelled by the block after its point of projection?

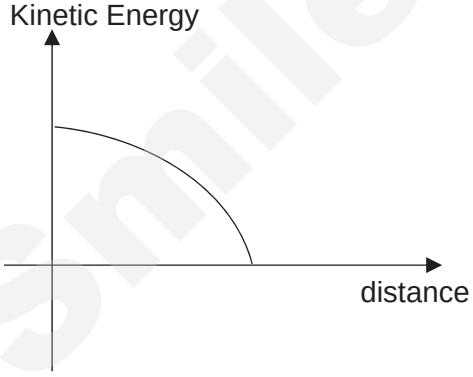
A



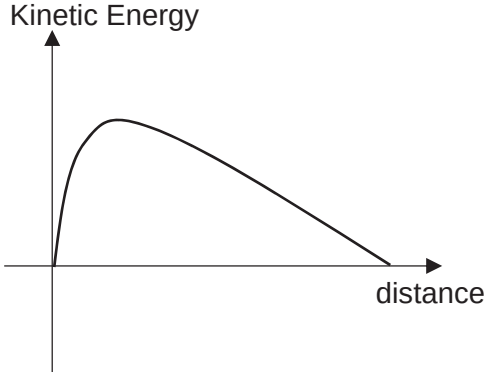
B



C



D



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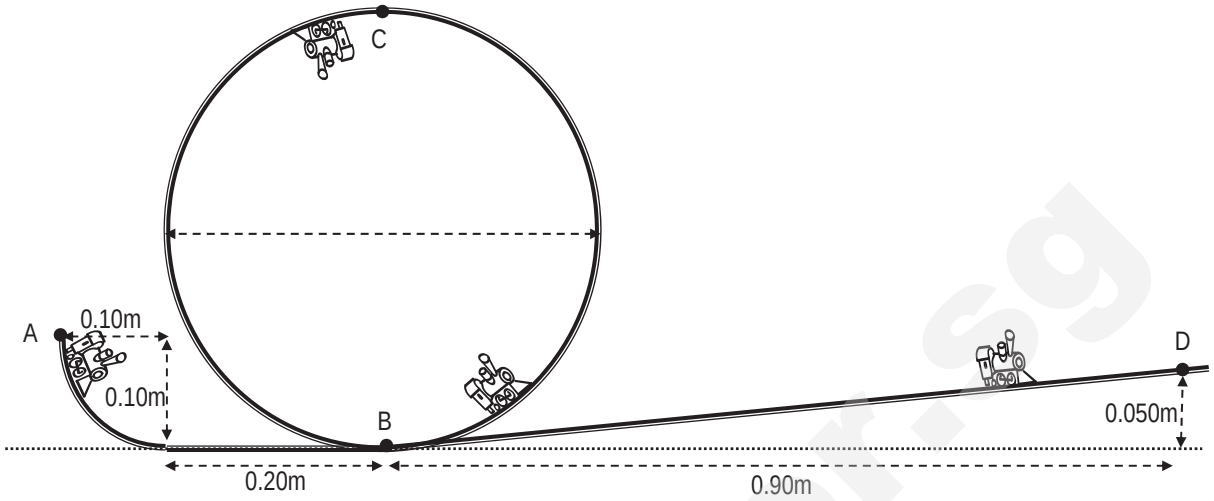
9 A toy train of mass *m* passes point **A** of the track with velocity *v*. What is the minimum value of *v* such that the train will travel up the loop of radius 0.20 m via points **B**, then **C** and eventually reach point **D**? You may ignore resistive forces in your calculation.



A 1.0 m s^{-1} **B** 1.4 m s^{-1} **C** 2.4 m s^{-1} **D** 2.8 m s^{-1}

10 What is the speed of a geostationary satellite that is orbiting Earth? The mass of Earth is taken to be 6.0×10^{24} kg.

A 3.08×10^{3} m s^{-1} **B** 4.71×10^{4} m s^{-1} **C** 1.80×10^{5} m s^{-1} **D** 4.23×10^{7} m s^{-1}

11 A ball which is thrown upward near the surface of Earth with velocity *v* will come to rest five seconds later. If the ball were to be thrown upward with the same velocity *v* on Planet X, it would still be moving upward at 31 m s^{-1} after five seconds.

What is the ratio $\frac{\text{gravitational field strength near surface of Planet X}}{\text{gravitational field strength near surface of Earth}}$?

A 0.16 **B** 0.37 **C** 0.53 **D** 0.63

12 Which of the following statements is *not true* for an oscillating body when light damping is present?

A The damping force is always in the opposite direction to the velocity of the body.

B The damping force is always in the opposite direction to the acceleration of the body.

C The presence of light damping changes the period of oscillation.

D The presence of light damping changes the maximum potential energy of the body.

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13 A fixed mass of ideal gas in a thermally insulated container is compressed. After compression, the temperature of the gas would have

A fallen, since more molecules bombard the container so they must be moving slower.

B fallen, since the molecules collide more frequently with each other so their average speed is slower.

C remained constant if the compression is very slow.

D risen, since doing work on the gas increases the kinetic energy of the gas molecules.

14 Two vessels X and Y, of volumes V_X and V_Y respectively, are kept at temperatures T_X and T_Y. They are filled with the same ideal gas and are connected via a narrow tube.

What is the ratio $\frac{\text{number of molecules in X}}{\text{number of molecules in Y}}$?

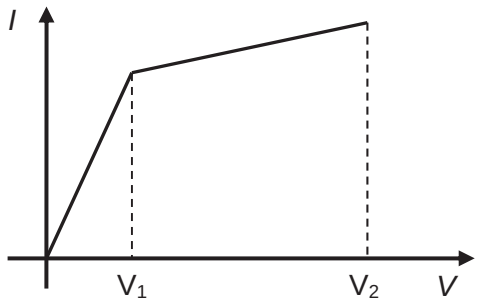
A $\frac{T_X V_X}{T_Y V_Y}$ **B** $\frac{T_X V_Y}{T_Y V_X}$ **C** $\frac{T_Y V_Y}{T_X V_X}$ **D** $\frac{T_Y V_X}{T_X V_Y}$

15 A potential difference is applied between the electrodes of a gas discharge tube of area 1.3×10^{-3} m^2 so that the gas is ionised into positively charged particles and electrons.

The gas carries a current of 12.2 mA and the number of electrons passing any point in the gas per unit time is 2.54×10^{16} s^{-1}. Given that the charge on each positively charged particle is 3.20×10^{-19} C and the number of the positively charged particles per unit volume is 1.0×10^{19} m^{-3}, what is the drift velocity of these positively charged particles in the gas?

A 0.98 m s^{-1} **B** 1.96 m s^{-1} **C** 3.91 m s^{-1} **D** 7.82 m s^{-1}

16 The graph below shows the variation of current I through an electrical component with the potential difference V across the component.



The resistance of the component is

A constant from 0 to V_1, then increases to another constant from V_1 to V_2.

B constant from 0 to V_1, then decreases to another constant from V_1 to V_2.

C constant from 0 to V_1, then decreases continuously from V_1 to V_2.

D constant from 0 to V_1, then increases continuously from V_1 to V_2.

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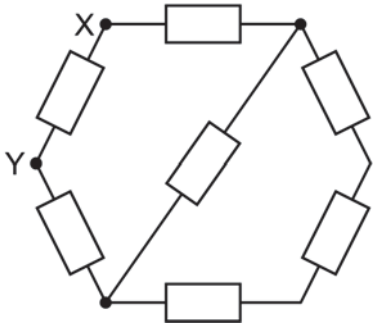
17 The diagram shows a network of 7 resistors, each with resistance R.



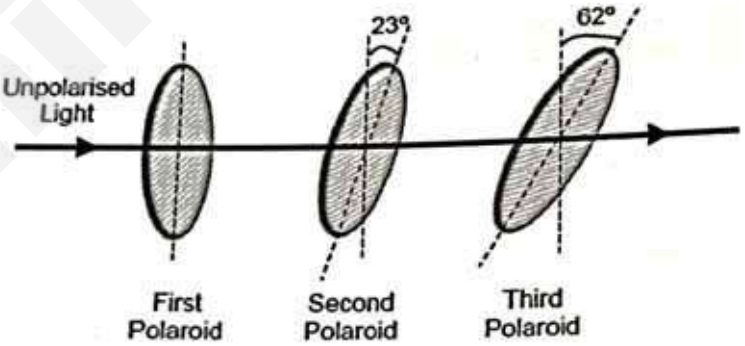
What is the resistance between points X and Y?

A $\frac{2}{3}R$ **B** $\frac{3}{5}R$ **C** $\frac{7}{11}R$ **D** $\frac{11}{15}R$

18 In a transverse progressive wave with a period of 0.060 s, the least distance between two adjacent points which have a phase difference of 90° is 0.20 m. What is the time taken for the wave to travel a distance of 4.00 m?

A 0.30 s **B** 0.60 s **C** 1.20 s **D** 1.50 s

19 Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at 23° and 62° respectively to that of the first polaroid, as shown in the diagram below.



When unpolarised light of amplitude A_o is incident on the stack of polaroids, its amplitude after passing through the first polaroid is A_1, and becomes A_2 after it passes through the second polaroid, and subsequently A_3 after it passes through the third polaroid. What is the value of $\frac{A_3}{A_1}$?

A 0.25 **B** 0.31 **C** 0.43 **D** 0.72

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20 A space shuttle orbits at a height of 330 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

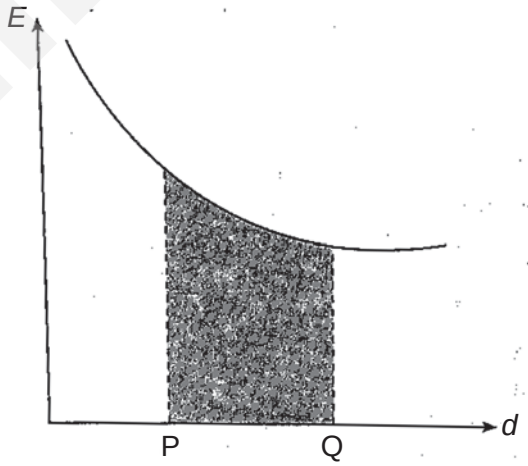
The observer views the panels with a telescope that has an aperture diameter of 85 mm. Assume that the panels act as point sources of light for the observer. Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
A	Yes	5.9×10^{-6}
B	Yes	7.3×10^{-5}
C	No	5.9×10^{-6}
D	No	7.3×10^{-5}

21 A single slit that is 1.0 mm wide is illuminated by light which has a wavelength of 450 nm. What is the width of the central maximum in the diffraction pattern produced on a screen 5.0 m away?

A 1.1 mm **B** 2.2 mm **C** 4.5 mm **D** 7.2 mm

22 The graph below shows the variation of the electric field strength *E* with distance *d* along a straight line in an electric field. What does the shaded area under the curve between P and Q represent?



A The work done by the electric field to move a charge from P to Q.

B The total charge that moves between P and Q.

C The power dissipated when moving a unit charge from P to Q.

D The potential difference between P and Q.

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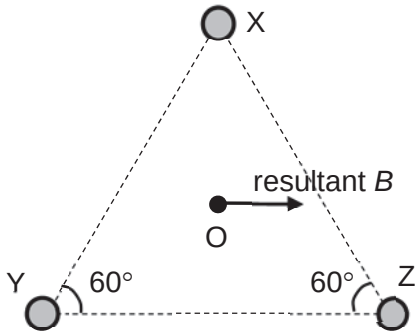
23 Three parallel conductors, all carrying currents of the same magnitude, pass vertically through the three corners X, Y and Z of a horizontal equilateral triangle as shown in the diagram below. A resultant magnetic flux density *B* acts at the centre O of the triangle, in the direction as shown below. What must be the directions of the currents in X, Y and Z?



	Into the page	Out of the page
A	X	Y and Z
B	Z	X and Y
C	Y and Z	X
D	X, Y and Z	None

24 An electron moves along the axis of a solenoid carrying current. Which of the following is a correct statement about the electromagnetic force acting on the electron?

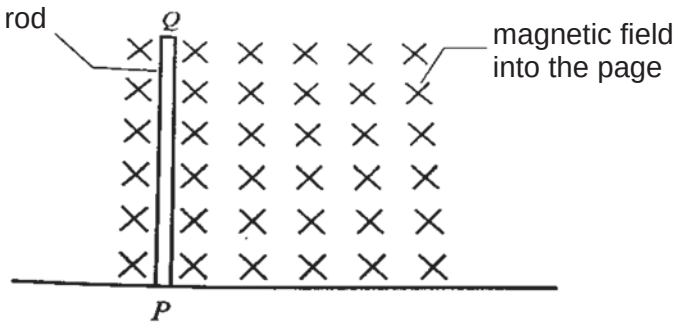
A No force acts.

B The force acts in the direction of motion.

C The force acts against the direction of motion.

D The force acts radially outward towards the solenoid.

25 A vertical rod PQ is hinged to a flat surface at the end P and placed in a uniform magnetic field that acts into the page, as shown in the diagram. When the rod is lightly pushed to the right at the end Q, it swings downwards while still hinged at P.



Just before the end Q hits the flat surface, which of the following statements is correct?

A Q is at a higher electrical potential than P.

B An upward magnetic force acts on the rod.

C An induced current flows to Q from P

D The rod rotates clockwise with a constant angular speed.

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26 A steady current I dissipates a certain power in a variable resistor, set at 12 Ω. To dissipate the same power when a sinusoidal alternating current is used, the resistor has to be set at 3 Ω. What is the r.m.s. value of the alternating current?

A $\frac{1}{\sqrt{2}}I$ **B** I **C** $\sqrt{2}\,I$ **D** $2\,I$

27 The four energy levels of the hydrogen atom and their corresponding energy values are

Level	Energy / eV
P	-13.60
Q	-3.40
R	-1.50
S	-0.85

A spectral line of 488 nm could result from an electron transition between levels

A Q and P **B** R and P **C** R and Q **D** S and Q

28 What is the wavelength of a beam of electrons accelerated through a potential difference of 5200 V?

A 1.7×10^{-11} m **B** 2.4×10^{-10} m **C** 1.4×10^{-7} m **D** 2.8×10^{-6} m

29 The deviation of alpha particles by thin metal foils through angles ranging from 0° to 180° can be explained by

A random motion of alpha particles.

B diffraction of the alpha particles through the metal due to the wave properties of the alpha particles.

C scattering by small but heavy regions of positive charges.

D scattering by the free electrons in the metal foils.

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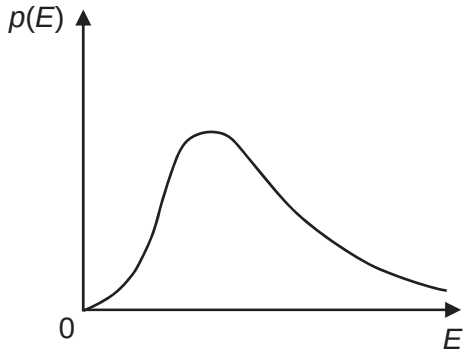
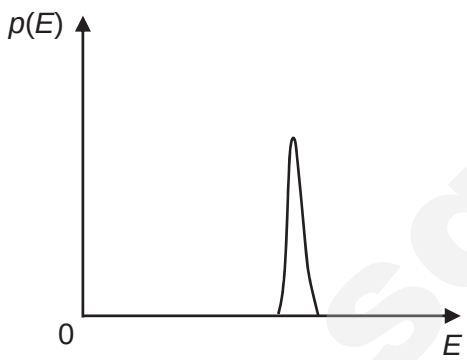
30 Which of the following graphs could represent $p(E)$, the distribution of the energies E of alpha particles that are emitted from a given source?

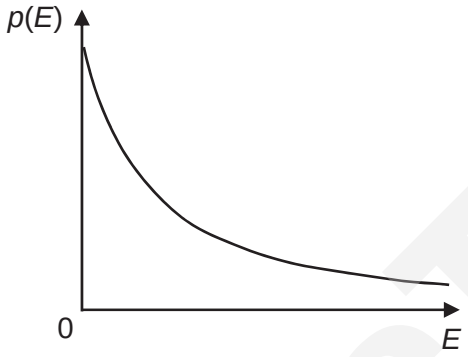
A



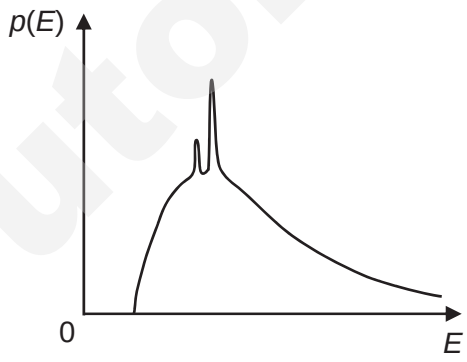
B



C



D



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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS 9749/02

Paper 2 Structured Questions

18 September 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
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Total	

This document consists of **19** printed pages.

[Turn over

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/^{o}C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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1 **(a)** State how force is related to linear momentum.

.....

.....

..... [2]

(b) In a laboratory experiment a small metal cylinder containing liquid carbon dioxide is attached to a trolley as shown in Fig 1.1. The trolley is initially at rest. When the cylinder is punctured, carbon dioxide gas rushes out and the trolley accelerates.

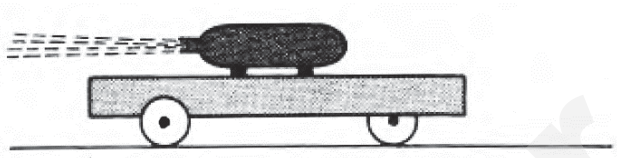

Fig. 1.1

(i) Using Newton's laws of motion, explain the origin of the force that is accelerating the trolley.

.....

.....

.....

.....

.....

..... [3]

(ii) The trolley and cylinder have a mass of 0.68 kg and they reach a maximum speed of 2.7 m s^{-1}. The total mass of carbon dioxide initially in the cylinder is 12 g.

1. Write an equation relating the initial and final velocities of the trolley-cylinder system in terms of the average acceleration *a* of the trolley-cylinder system, and the time *t* taken for this system to achieve maximum speed.

..... [1]

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2. Write an equation relating the average ejection speed v_g of the carbon dioxide gas, the average accelerating force F exerted on the gas and the time t taken for all the gas to be ejected.

..... [1]

3. Hence calculate the average ejection speed of the carbon dioxide gas.

average ejection speeed = ... m s^{-1} [2]

(iii) The cylinder is then removed from the trolley, and the trolley is given a push so that it collides head-on with a second stationary trolley which is identical to the first one.

Describe the subsequent motion of the trolleys if they make

1. an elastic collision,

.....

..... [2]

2. a completely inelastic collision.

.....

..... [1]

2 (a) (i) Define *gravitational potential* at a point in a gravitational field.

.....

.....

..... [1]

(ii) Explain why gravitational potential is always negative.

.....

.....

..... [1]

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(b) Fig. 2.1 shows the variation of gravitational potential between the surface of Moon and the surface of Earth along the line joining their centres.

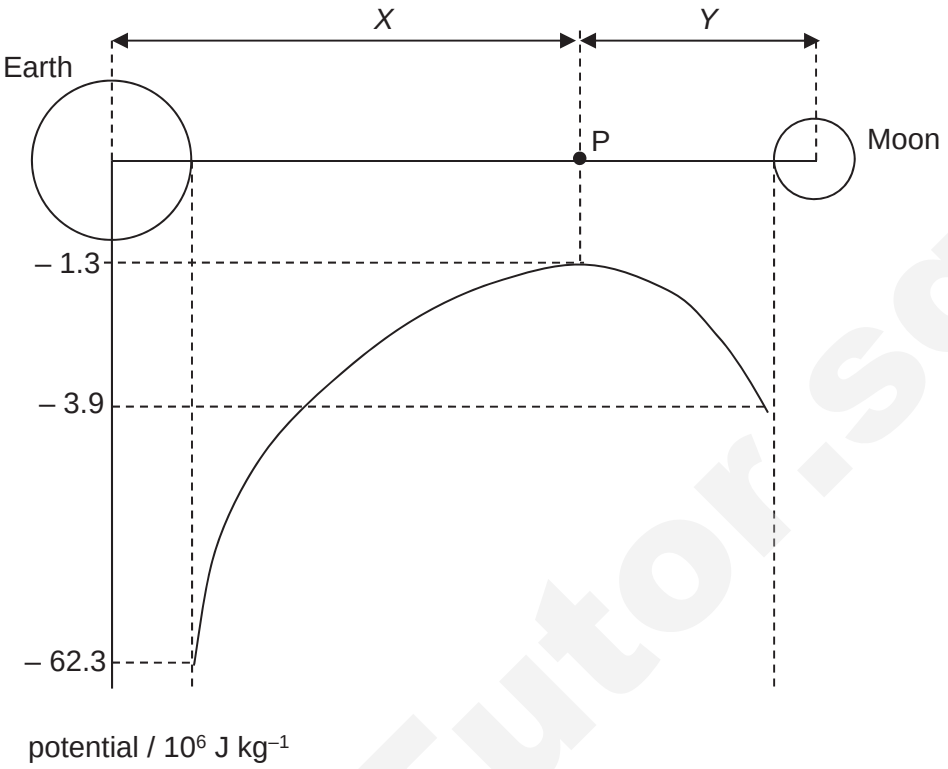

Fig. 2.1

Explain why the gradient of the graph near the surface of Earth and that near the surface of Moon have opposite signs.

.....

.....

.....

..... [2]

(c) Two moons A and B move in circular orbits about a planet, as illustrated in Fig. 2.2.

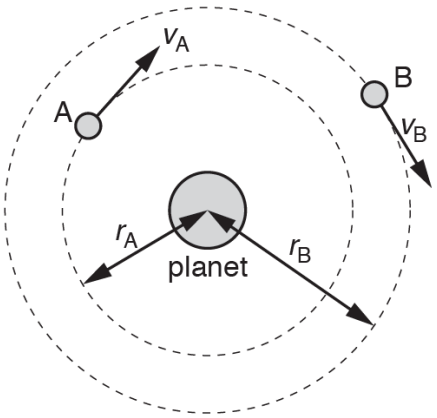

Fig. 2.2

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Moon A has an orbital radius r_A of 1.3×10^8 m, linear speed v_A and orbital period T_A.
Moon B has an orbital radius r_B of 2.2×10^{10} m, linear speed v_B and orbital period T_B.

(i) Determine the ratio

1. $\frac{v_A}{v_B}$, and

ratio = ... [3]

2. $\frac{T_A}{T_B}$.

ratio = ... [1]

(ii) The planet spins about its own axis with angular speed 1.7×10^{-4} rad s^{-1}. Moon A is always above the same point on the planet's surface. Determine the orbital period T_B of moon B.

T_B = ... s [2]

3 At a shooting gallery in a fun fair, a mobile target lion sways horizontally with simple harmonic motion as shown in Fig. 3.1. Hidden in a metal container below the lion target is a motor-driven circular rotating disc with a knob that slides along a frictionless groove attached to the lion. As the disc rotates with constant angular frequency, it pushes the lion target horizontally left and right.

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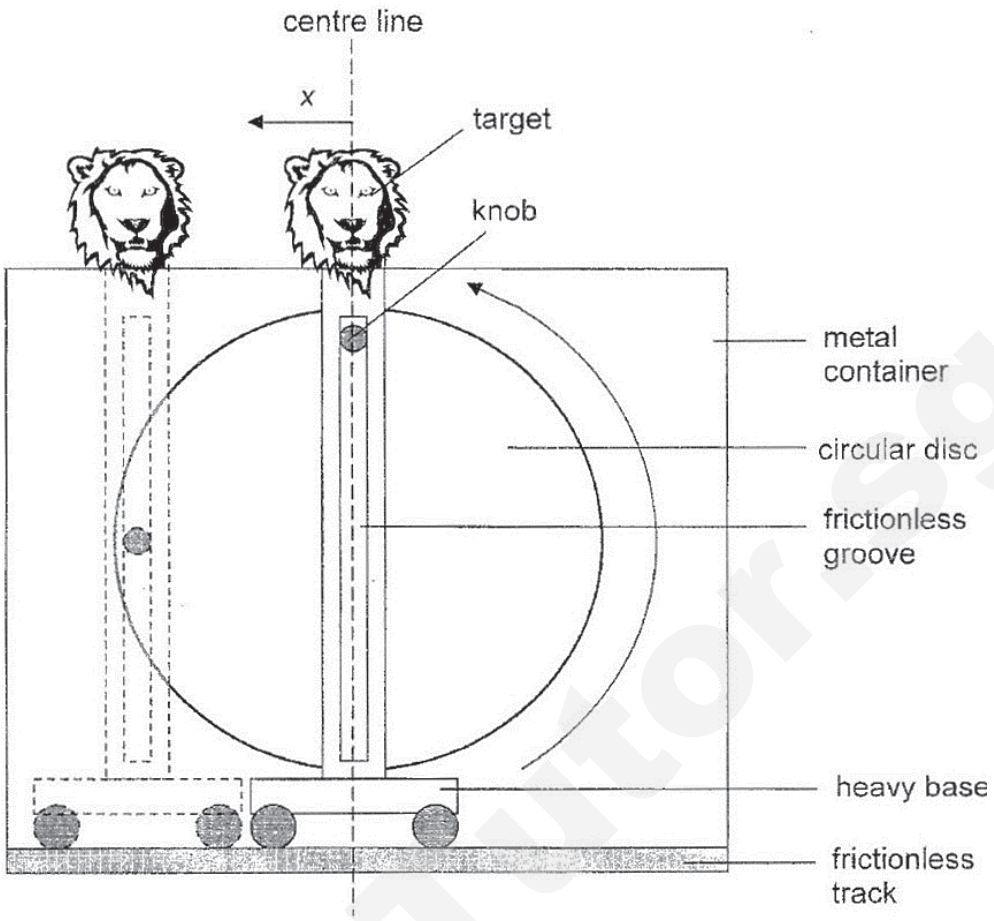

Fig. 3.1

Fig. 3.2 shows how the kinetic energy *KE* of the lion target varies with its displacement *x* from the centre line and Fig. 3.3 shows how its velocity *v* varies with its displacement *x*.

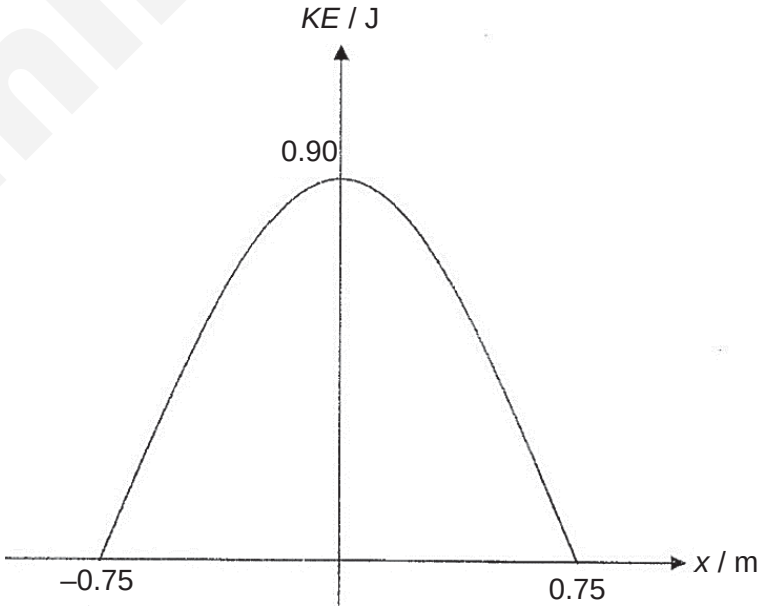

Fig. 3.2

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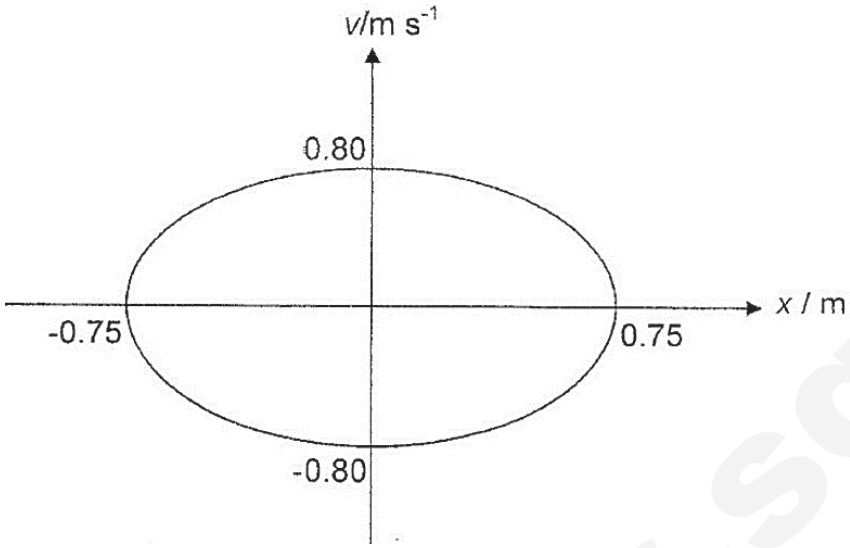

Fig. 3.3

(a) Deduce, from Fig. 3.2 and Fig. 3.3,

(i) the mass of the lion target,

mass = ... kg [2]

(ii) the number of revolutions per second of the circular disc,

number of revolutions per second = ... s^{-1} [2]

(iii) the speed of the knob when the displacement of the lion is maximum.

speed = ... m s^{-1} [2]

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(b) When the lion target is at its leftmost position, a ball was tossed towards the middle position between the leftmost position and the centre line, with the aim of hitting the lion target. The ball takes 0.74 s to reach that middle position. Determine and explain whether the ball will hit the lion target right at its nose.

.....

.....

..... [2]

4 A positively charged particle passes through a region of uniform magnetic field of flux density 0.75 T, as shown in Fig. 4.1.

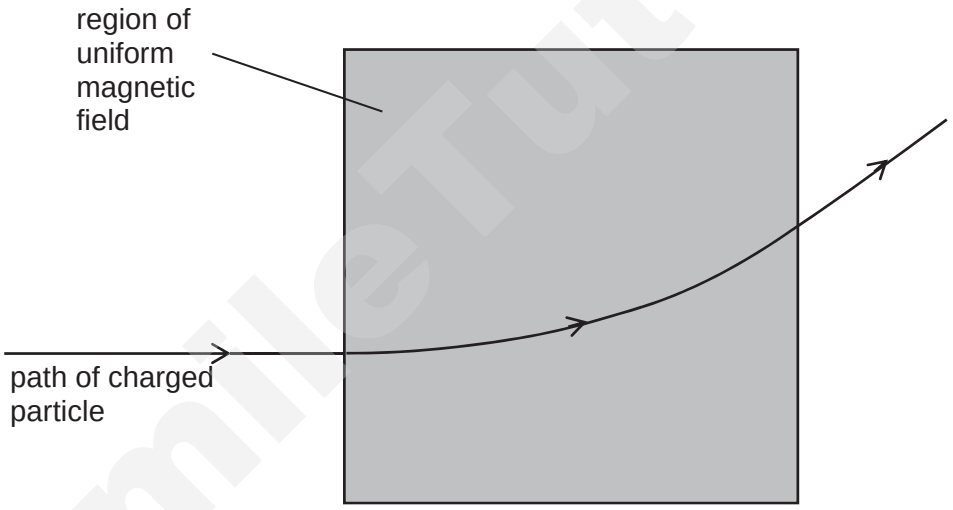

Fig. 4.1

The radius *r* of the path of the particle in the magnetic field is 25 cm.

(a) Define the *tesla*.

.....

.....

..... [2]

(b) State the direction of the magnetic field.

..... [1]

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(c) **(i)** The specific charge of a particle is the ratio of its charge to its mass, $\frac{q}{m}$. Given that the speed of the particle is 9.0×10^6 m s^{-1}, calculate the specific charge of the particle.

specific charge = ... C kg^{-1} [3]

(ii) Using your answer in **(i)**, suggest the name of a possible charged particle which has entered the uniform magnetic field. Show your working.

.....

..... [2]

(iii) Explain how the path of the charged particle in the uniform magnetic field will be different if it were an electron projected into the field with the same speed as the positively charged particle in **(i)**.

.....

.....

..... [2]

5 **(a)** State Faraday's law of electromagnetic induction.

.....

.....

..... [1]

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(b) Induction heating is commonly used for heating up electrically conductive materials in a clean, efficient and controlled manner. In industry, induction heating is a simple and reliable method for bottle sealing. It welds a circular piece of aluminium foil across the necks of medicine and drink bottles.

As shown in Fig. 5.1, a bottle is first filled at position 1. A plastic cap, complete with a piece of aluminium foil, is applied to the bottle neck at position 2. The foil is also coated with 'hot-melt glue' before being screwed onto the top of the bottle during manufacture. As the bottle passes under the induction heater (positions 3, 4, 5) on the production line, the foil is rapidly heated. The heat generated melts the glue and seals the foil onto the top of the bottle by position 5. When the cap is removed, the foil remains attached, providing an airtight seal and preventing any tampering or contamination of the bottle contents until the customer pierces the foil.

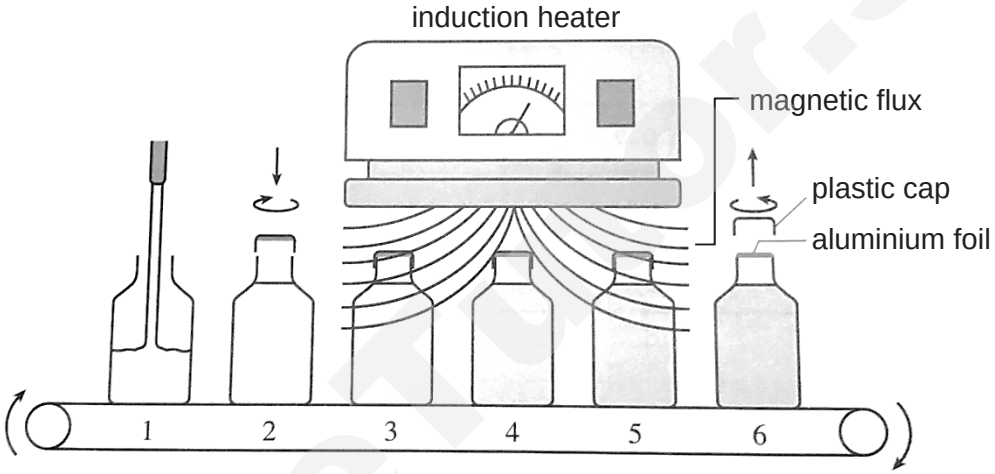

Fig. 5.1

(i) State one advantage of using induction heating.

.....

.....

..... [1]

(ii) Using laws of electromagnetic induction where appropriate, explain how the glue is melted.

.....

.....

.....

.....

.....

.....

..... [3]

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(iii) The amount of heat produced in the aluminum foil can be estimated using a small coil placed underneath the induction heater. The coil has a cross-sectional area of 2.40 cm^2 and contains 150 turns of wire. The resistance of the coil is $6.8 \times 10^{-3}\ \Omega$. Given that the magnetic flux density increased from zero to 500 mT in 0.30 s,

1. calculate the maximum magnetic flux linkage through the coil, and

maximum magnetic flux linkage = ... Wb [2]

2. determine the power dissipated by the coil.

power dissipated = ... W [2]

(iv) Explain if this method can be used to fix a plastic seal around the bottle instead.

.....

.....

..... [1]

6 **(a)** Describe three observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

1 .....

.....

2 .....

.....

3 .....

..... [3]

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(b) Light of wavelength λ is incident on a metal surface having a work function energy Φ. Photoelectrons of maximum kinetic energy E_{MAX} are emitted from the surface.

The variation with $1/\lambda$ of E_{MAX} is shown in Fig. 6.1.

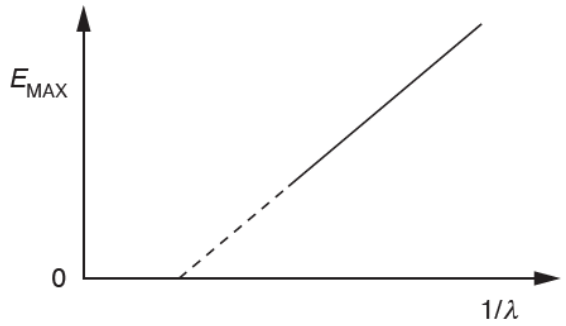

Fig. 6.1

(i) Explain why the gradient of the line in Fig. 6.1 does not depend on the type of the metal surface.

.....

.....

..... [2]

(ii) The work function energy of sodium is 2.28 eV. Determine the minimum wavelength λ_o at which E_{MAX} is zero.

minimum wavelength = ... m [2]

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(c) An electron gun is used to shoot a beam of electrons towards a screen, at a speed of 6.00×10^6 m s^{-1}, through a slit of width 2.00 mm. Determine the distance between the slit of the gun and the screen, in order to see the beam of electrons spread by 1.00 cm on the screen because of the uncertainty principle.

distance = ... m [3]

7 The walls of music halls are acoustically covered with a sound-absorbing panel that is able to absorb certain sound frequencies more than others.

One particular design is to use the resonance of a perforated panel as shown in Fig. 7.1.

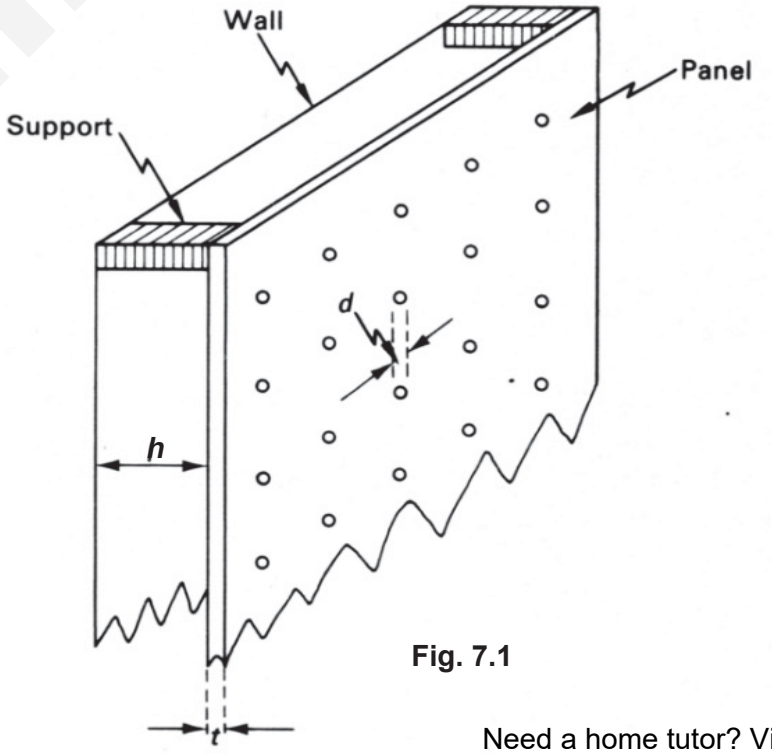

Fig. 7.1

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It is found that this panel resonates at a particular frequency and hence can absorb sounds of that frequency more than others. A suggested formula for this resonant frequency f is given as:

$$f = k\sqrt{\frac{x}{h(t + 0.8d)}} \qquad \text{--- Equation 7.1}$$

where $k = 5000$ mm s^{-1},
h = depth of airspace with unit mm,
t = thickness of panel with unit mm,
d = hole diameter with unit mm, and
x = percentage of panel surface area occupied by holes (e.g. $x = 10$ %)

Using identical hardboard panels having holes of the same diameter of 10 mm, the resonant frequencies f for different x values are measured, keeping h and t constant. The results are shown in Fig. 7.2:

x / **%**	2	4	6	8	10	12
f / Hz	530	750	920	1070	1190	1300

Fig. 7.2

(a) Using the results from Fig. 7.2, state and explain whether the formula for f given in Equation 7.1 is correct.

.....

..... [3]

(b) Determine suitable values for h and t when $x = 10$ %, such that the results from Fig. 7.2 satisfy the given formula for f in Equation 7.1.

h = ... mm

t = ... mm [2]

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(c) Using a panel with x fixed at 10 % and d fixed at 5 mm, the engineer decides to investigate the effect of filling the air space with 2 different absorbers. He obtains the absorption characteristics shown in Fig. 7.3.

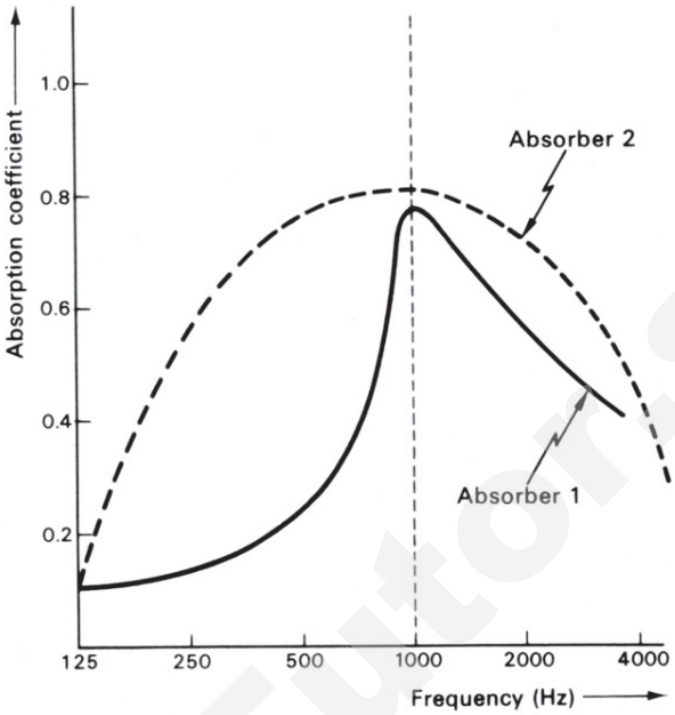

Fig. 7.3

Absorption coefficient is an indication of how much sound waves can be absorbed i.e. the higher the absorption coefficient, the stronger the absorption.

(i) Using your knowledge on resonance, state one effect that absorbers have on the resonant frequency when they are inserted into the air space.

.....

..... [1]

(ii) State and explain which of the two absorbers would be preferred in a room in which

1. absorption over a wide frequency range is required,

.....

..... [1]

2. sounds below 500 Hz need amplification.

.....

..... [1]

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8 In 2012 skydiver Felix Baumgartner jumped out of a helium-filled balloon from a height of 39 km above sea level. His free fall of over 36 km lasted 4 minutes and 20 seconds. In this free fall, he became the first person whose speed exceeded the speed of sound 330 m s^{-1}, without the use of an aeroplane or rocket.

During the fall, Felix Baumgartner opened his parachute at about 1500 m above sea level, when his speed is 192 km hr^{-1}, and he landed safely 15 minutes later. All height and speeds were recorded by GPS.

Some data on the air atmosphere and helium is collected and given in Fig. 8.1.

	sea level	**39 km above sea level**
Temperature of atmosphere / ^oC	15	-25
Atmospheric pressure / Pa	101 000	318
Air density	-	0.00447
Helium density / kg m^{-3}	-	0.00065

Fig. 8.1

(a) Using data given in Fig. 8.1, determine the minimum volume of helium required in the balloon at sea level, for a skydiver in the helium-filled balloon to reach a height of 39 km above sea level at constant speed. Assume that the total mass of the skydiver and the helium-filled balloon is 3140 kg, and that helium behaves as an ideal gas.

volume required at sea level = ... m^3 [3]

Two main forces acting on the skydiver of mass m are his weight and air resistance. The air resistance F can be written as follows

$$F = \tfrac{1}{2} C_D A p v^2$$

where p is the density of air, A is effective cross-sectional area and C_D is the drag coefficient.

(b) **(i)** Show that the terminal speed v_T that can be achieved by the skydiver as he falls is given by

$$v_T = \sqrt{\frac{2mg}{C_D A p}}$$

[1]

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(ii) Explain why the skydiver's terminal speed will not be constant as he falls.

.....

..... [1]

(c) The acceleration a of the sky diver when he is falling at a speed v is given by

$$a = g\left(\frac{v^2}{v_T{}^2} - 1\right) \qquad \text{--- Equation 8.1}$$

The variation of the skydiver's speed with time as he falls is shown in Fig 8.2. The terminal speed v_T based on the expression given in **(b)(i)** is also plotted in Fig. 8.2 (denoted by the dashed line).

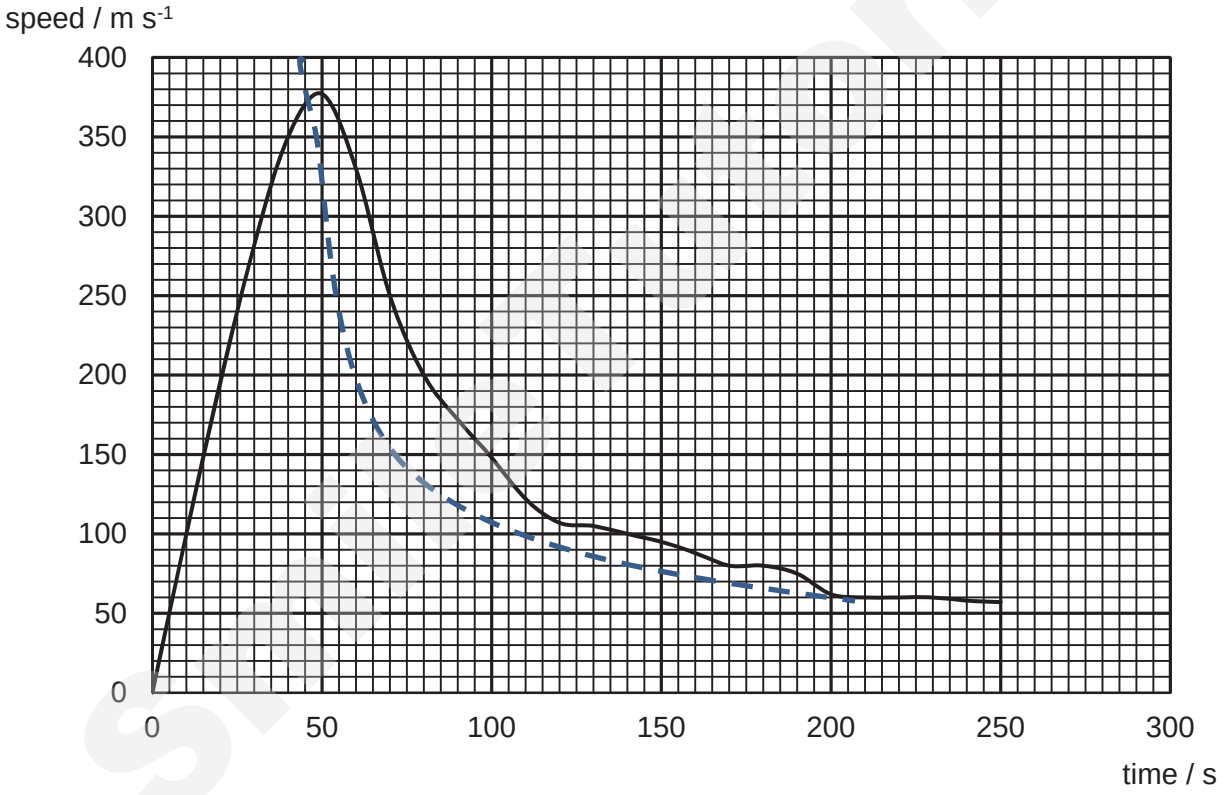

Fig. 8.2

(i) Deduce from Fig 8.2 the duration of time when the skydiver exceeds the speed of sound during his fall.

duration = ... s [1]

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(ii) Use Fig 8.2 to determine the total distance fallen when the sky diver reaches his maximum speed.

total distance fallen = ... m [2]

(iii) Using Fig. 8.2 and Equation 8.1, describe and explain the variation in the speed of the skydiver from time = 50 s to 250 s.

.....

.....

.....

..... [2]

(d) **(i)** Suggest why a helium-filled balloon is used to bring the skydiver to a height of 39 km above sea level, instead of using an aircraft.

.....

..... [1]

(ii) Suggest a major health hazard to the skydiver at such a high attitude, even with the use of oxygen supply.

.....

..... [1]

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Paper 3 Longer Structured Questions

21 September 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

You are advised to spend about one and a half hours on Section A, and about thirty minutes on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Total	

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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Section A

Answer **all** the questions in the spaces provided.

1 A hot air balloon P is moving vertically upward at a uniform speed when weather condition turns windy. A constant breeze blows horizontally across the sky at a speed 4.0 m s^{-1}, which causes the hot air balloon to travel with a resultant velocity 11 m s^{-1} at an angle θ to the horizontal, as shown in Fig. 1.1 below.

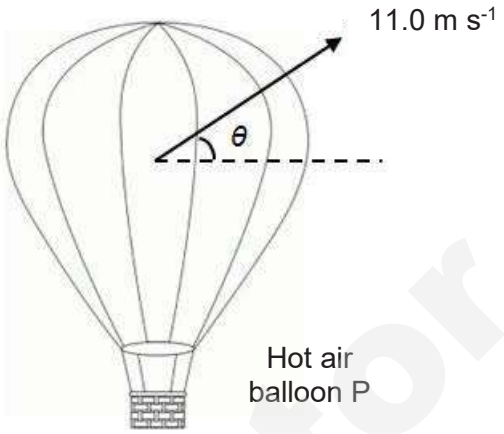

Fig. 1.1

A sandbag is released from the balloon P. Ignore the effects of air resistance. Assuming that the sandbag has yet to land on the ground after 2.3 s, and that the velocity of balloon P is not affected by the release of the sandbag,

(a) determine the horizontal distance of the sandbag from balloon P after 2.3 s, and

horizontal distance = ... m [1]

(b) show that the vertical distance of the sandbag from balloon P after 2.3 s is 26 m. [2]

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(c) There is a second hot air balloon Q which is at a stationary position below the first hot air balloon P. At the instant when the released sandbag passes in front of this second air hot balloon Q at 2.3 s, the person inside balloon Q throws another sandbag at this first sandbag that was released from P. The second sandbag is thrown from Q at an angle of 45° below the horizontal.

(i) Determine the speed at which the second sandbag is thrown from Q if both sandbags reach the ground at the same time.

speed = ... m s^{-1} [2]

(ii) The person inside Q wants the sandbag that was thrown out from Q in **(i)** to reach the ground within a shorter time. Therefore he throws out another sandbag from Q with the same speed and angle of projection as the sandbag which he threw out in **(i)** but this time, he uses a heavier sandbag. Comment on whether he will succeed.

.....

..... [1]

2 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 2.1.

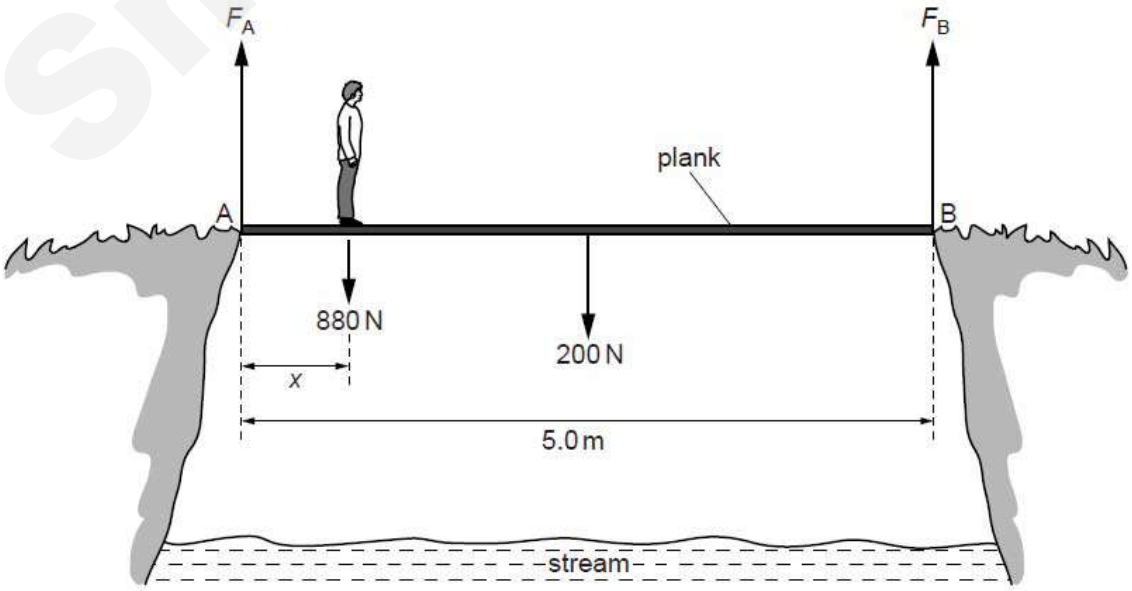

Fig. 2.1

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A man of weight 880 N stands at a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B. As the man moves along the plank, the plank is always in equilibrium.

(a) **(i)** Define *moment of a force*.

.....

..... [1]

(ii) Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

.....

.....

.....

..... [2]

(iii) The man stands at a distance x = 0.50 m from end A. Determine the magnitude of F_B.

F_B = ... N [2]

(b) The variation with distance x of the magnitude of force F_A is shown in Fig. 2.2.

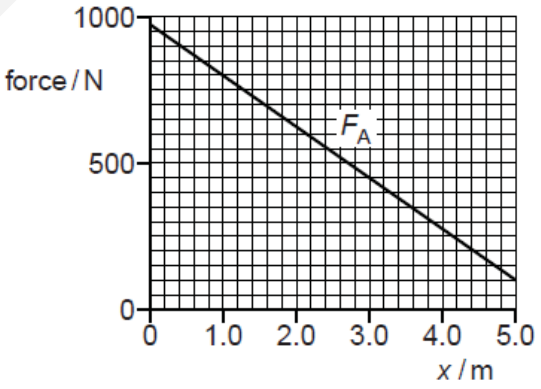

Fig. 2.2

On Fig. 2.2, sketch a graph to show the variation with x of the magnitude of force F_B. [2]

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3 A student attempts to set up a "Rube Goldberg Machine", which is a contraption consisting of a series of devices that perform simple tasks which are linked together to produce a domino effect, where the activation of one device triggers the next device in the sequence.

A part of the contraption is shown in Fig 3.1. It consists of a small block of mass 40 g, initially at rest, which slides down a rough slope from X to P. When the block reaches point P, it attains a speed of 0.35 m s^{-1}.

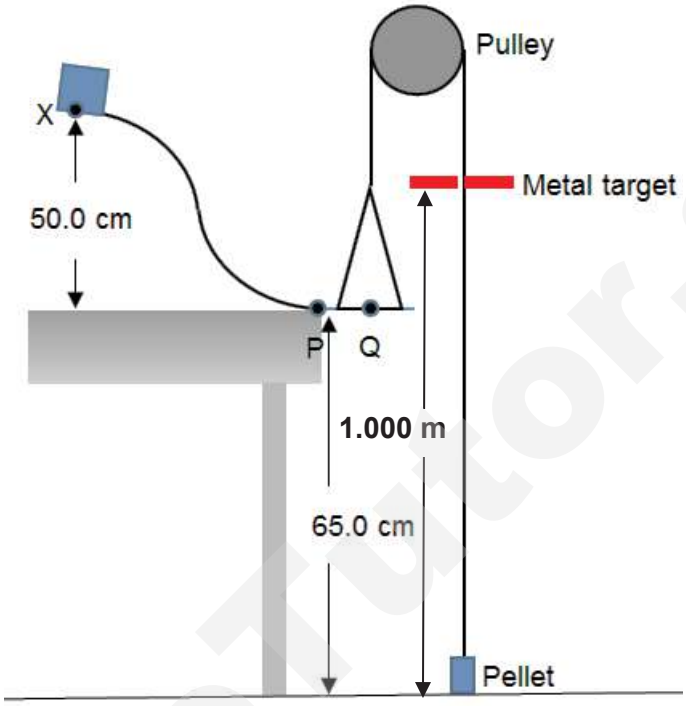

Fig. 3.1

(a) Determine the work done against friction when the block slides from X to P.

work done = ... J [2]

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(b) At P, the block continues to slide forward a little and comes to a complete stop at point Q on a movable platform connected to a pulley. Its weight causes the pulley to turn and the block eventually hits the ground 65.0 cm below, lifting a small 15 g rectangular pellet from the ground in the process.

(i) Determine the speed of the pellet just as the 40 g block hits the ground.

speed = ... m s^{-1} [2]

(ii) The contraption is designed such that when the pellet hits a metal target during its upward motion, it will make a loud sound. The target is placed 1.000 m above the ground. State and explain whether the pellet will hit the target, showing your working clearly.

.....

.....

..... [3]

(iii) State an assumption you have made in your calculation in **(ii)**.

.....

..... [1]

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4 A turntable is rotating at a constant speed of 15 revolutions per minute. A small five-cent coin of mass 1.56 g is placed at the rim of the turntable and it moves with the turntable without slipping.

(a) Show the angular velocity of the rotating coin is 1.57 rad s^{-1}. [1]

(b) Given that the kinetic energy of the coin is 2.5×10^{-5} J, determine the radius of the turntable.

radius = ... m [2]

(c) If the maximum friction between the coin and the turntable is 0.012 N, calculate the maximum number of complete revolutions that the turntable can make per minute, such that the coin can still remain on the turntable.

maximum number of revolutions per minute = ... min^{-1} [3]

(d) If the rotational speed of the turntable continues to increase, the coin is observed to slip off the turntable and fall to the ground. Describe the path of the coin after it leaves the turntable until it reaches the ground.

.....

..... [2]

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5 **(a)** In order to determine the internal resistance of a 12.00 V battery, a student sets up the circuit shown in Fig. 5.1. The rheostat CD has a maximum resistance of 1000 Ω.

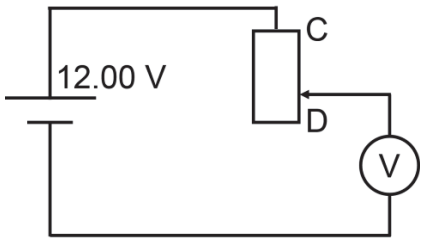

Fig. 5.1

When the sliding contact of the rheostat is placed at C, the voltmeter reading is 11.99 V. When the sliding contact moves from C to D, the voltmeter reading drops from 11.99 V to 11.00 V.

(i) State the potential difference across the internal resistance of the battery when the sliding contact of the rheostat is placed at C.

potential difference = ... V [1]

(ii) Explain why the presence of internal resistance in the battery reduces its output power.

.....

..... [1]

(iii) Determine the internal resistance *r* of the battery and internal resistance *R* of the voltmeter.

r = ... Ω

R = ... Ω [4]

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(b) In another circuit shown in Fig. 5.2, a uniform wire AB of length 80.0 cm and resistance 1.5. Ω is connected in series with a resistor of 5.0 Ω and a cell of e.m.f. 9.0 V with internal resistance 1.0 Ω.

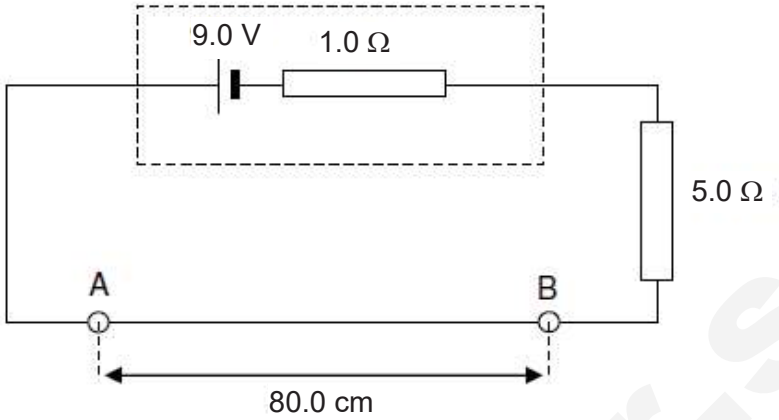

Fig. 5.2

(i) Calculate the potential difference across wire AB.

potential difference = ... V [2]

(ii) A cell C of e.m.f. 1.5 V and internal resistance 0.80 Ω is connected to the circuit in Fig. 5.2, as shown in Fig. 5.3. The movable contact D can be connected to any point along wire AB.

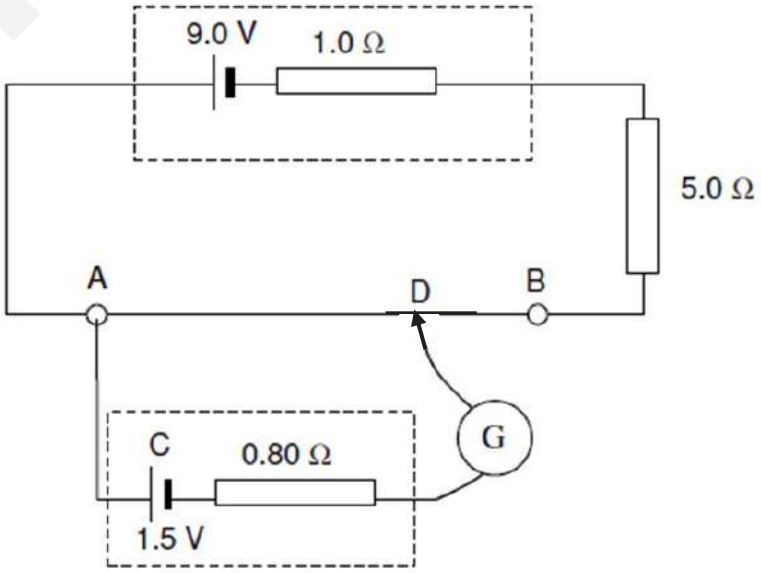

Fig. 5.3

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Calculate the length of AD when there is zero current in the galvanometer.

length = ... m [2]

6 **(a)** State in words the *first law of thermodynamics*.

.....

.....

..... [1]

(b) An adiabatic process is one in which no heat is supplied to or extracted from a system.

(i) Determine the change in the internal energy of an ideal gas when the gas does 600 J of work in an adiabatic process.

change in internal energy = ... J [1]

(ii) Hence describe how the temperature of the gas in **(i)** will change at the end of the adiabatic process.

.....

..... [1]

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(c) A heat pump is a device which works by changing the state of a gas through a cycle of operations such those shown in Fig. 6.1, changing the state of a sample of gas from A to B, then to C, and then to D, and eventually back to A.

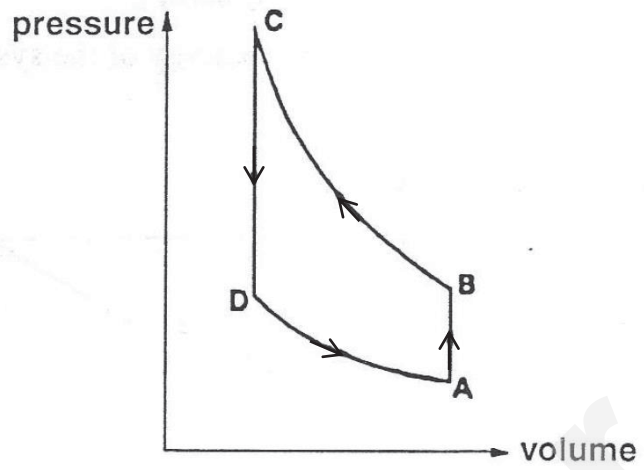

Fig. 6.1

Between A and B the gas absorbs heat from the atmosphere, and between C and D it delivers heat to the inside of a building. Processes BC and DA are adiabatic.

For a certain heat pump, the heat supplied to the gas during each part of the cycle and the corresponding work done on the gas are given in Fig. 6.2. The cycle is completed 20 times per second.

Section of cycle	Heat supplied to gas / J	Work done on gas / J
A → B	280	
B → C		
C → D	-400	
D → A		-70

Fig. 6.2

(i) Fill in the blank spaces in Fig. 6.2. [2]

(ii) Explain why the total change in the internal energy of the gas in the pump during a complete cycle must be zero.

.....

..... [1]

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(iii) Calculate the minimum average power of the motor required to run the pump.

minimum average power = ... W[2]

(iv) Calculate the average rate of supply of heat by the pump.

average rate of supply of heat = ... W[2]

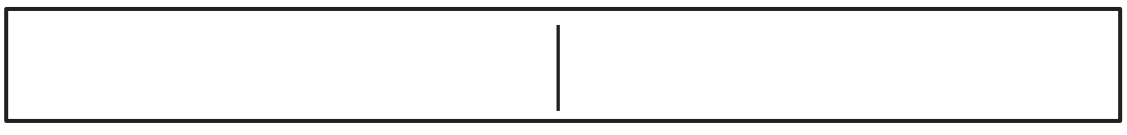
7 **(a)** Red and green light, of wavelengths 640 nm and 520 nm respectively, are simultaneously directed through a narrow slit onto a diffraction grating. The grating is at right angles to the light and has a line spacing of 1.60 μm.

(i) Complete Fig. 7.1 by calculating the values of all the angles of diffraction corresponding to different orders of maxima for both colours. [3]

order *n*	angle for red maximum / °	angle for green maximum / °
0		
1		
2		
3		

Fig. 7.1

(ii) Sketch on Fig 7.2 the approximate pattern that would be seen on a screen behind the diffraction grating. Label the red and green maxima **R** and **G** respectively. [2]



central maximum

Fig. 7.2

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(iii) Suggest and explain how the spacing of the maxima drawn on Fig. 7.2 can be used to determine whether the light is directed normal to the grating.

.....

.....

..... [2]

(iv) Explain why the same pattern will not be observed on the screen if the diffraction grating has irregularly spaced slits.

.....

..... [1]

(b) **(i)** The grating in **(a)** is replaced with a double-slit setup that has the same spacing between slits as the grating in **(a)**. Describe how the new pattern produced will differ from the one drawn in **(a)(ii)**.

.....

.....

..... [2]

(ii) The grating in **(a)** is replaced with a single slit whose slit width has the same value as the slit spacing of the grating in **(a)**. This produces another pattern. Determine the angle θ between two lines, drawn from the centre of the slit to the central maximum and to the first order red minimum in the pattern respectively.

θ = ... rad [1]

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Section B

Answer **one** question from this Section in the spaces provided.

8 **(a)** **(i)** Define *electric field strength*.

.....

..... [1]

(ii) With reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

.....

.....

..... [2]

(b) Electrons 'leak' easily from the surface of many stars, so these stars acquire a positive charge. The charging stops when the charge on the star is so large that protons at the surface of the star also begin to be repelled.

This occurs when the sum of the gravitational potential energy and the electric potential energy of a proton at the surface of the star is zero. The star is then considered to be in steady state. It is assumed that each star takes on the shape of a sphere.

(i) Write down an equation that relates the gravitational potential energy and the electric potential energy of a proton at the surface of a star that has just stopped charging, **defining clearly** all the symbols used in the equation.

.....

.....

..... [2]

(ii) Show that, in the steady state, the maximum charge carried by a star of a given mass is independent of its radius. [1]

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(iii) Calculate the maximum charge for Sun, which has a mass of 2.0×10^{30} kg.

maximum charge = ... C [1]

(c) Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart. Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 8.1.

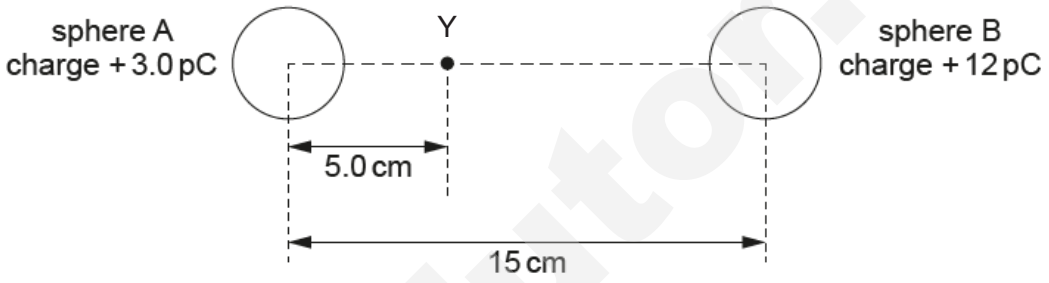

Fig. 8.1

Point Y lies on the line joining the centres of the spheres and is at a distance of 5.0 cm from the centre of sphere A.

(i) Explain why the electric field strength in both spheres is zero.

.....

.....

..... [1]

(ii) Show that the electric field strength is zero at point Y. Explain your working. [3]

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(iii) Explain how the electric field strength at point Y is related to the electric potential at that point.

.....

..... [1]

(iv) Calculate the electric potential at point Y.

electric potential = ... V [2]

(v) A silver-107 nucleus ($^{107}_{47}Ag$) has speed v when it is a long distance from point Y. Use your answer in **(iv)** to calculate the minimum value of v such that the nucleus can reach point Y.

v = ... m s^{-1} [2]

(d) Sphere B in Fig. 8.1 is removed and placed at the centre of two parallel, large metal plates which are connected to the terminals of a battery with e.m.f. 10 V, as shown in Fig. 8.2. The distance between the plates is 2.0 mm.

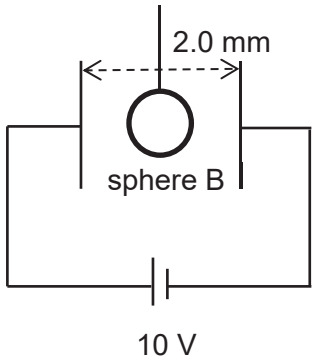

Fig. 8.2

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(i) Calculate the electric force F_1 exerted by the plates on sphere B.

F_1 = ... N [2]

(ii) Another conducting sphere C, which is initially uncharged and has a radius twice that of sphere B, is placed in contact with sphere B. Determine the new charge on sphere B after sphere C has been removed.

new charge = ... C [2]

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9 In 1954 the world's first nuclear-powered submarine, the USS Nautilus, was launched. Before that, submarines used diesel-electric power. Enriched uranium, which consists of a high percentage of uranium-235 isotope ($^{235}_{92}U$), was used as the source of fuel for USS Nautilus.

Naturally occurring uranium consists mainly of uranium-238 isotope ($^{238}_{92}U$) and only 0.72% of it is made up of $^{235}_{92}U$. It can be enriched to increase the percentage of $^{235}_{92}U$ by up to 90% so as to allow nuclear fission reaction to take place effectively.

(a) In the nuclear reactor of the submarine, the process of nuclear fission is caused by the bombardment of $^{235}_{92}U$ with a slow-moving neutron as described by the following equation:

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

(i) Explain what is meant by the nuclear binding energy of a uranium-235 nucleus.

.....

..... [1]

(ii) Sketch the variation of average binding energy per nucleon with nucleon number on Fig 9.1. In your sketch, mark the relative positions of $^{235}_{92}U$, barium-144 ($^{144}_{56}Ba$) and krypton-89 ($^{89}_{36}Kr$). [2]

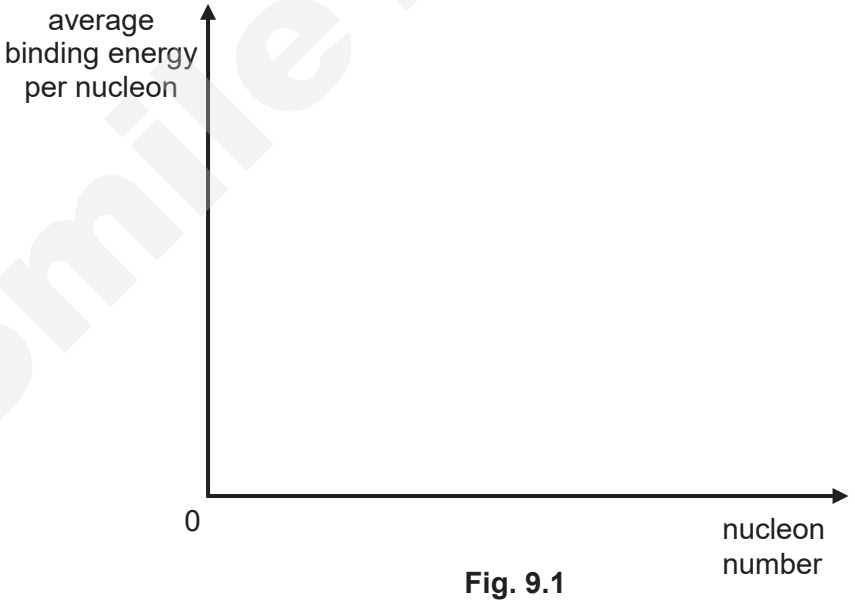

Fig. 9.1

(iii) Using the concept of binding energy, explain why the fission of $^{235}_{92}U$ into $^{144}_{56}Ba$ and $^{89}_{36}Kr$ results in a release of energy.

.....

.....

..... [2]

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(iv) The masses of some of the particles and nuclei involved in the reaction are given in Fig. 9.2.

	mass
$^{235}_{92}U$	235.044 *u*
$^{144}_{56}Ba$	143.923 *u*
$^{89}_{36}Kr$	88.917 *u*
$^{1}_{0}n$	1.009 *u*

Fig. 9.2

Calculate the energy released for one such fission reaction, to three significant figures.

energy released = ... MeV [3]

(v) When tested under laboratory conditions, the total kinetic energy of the products in the fission reaction was found to be 168 MeV. Suggest a reason for the difference (if any) between this value and your answer in **(iv)**.

.....

..... [1]

(vi) The nuclear reactor used to power the USS Nautilus has a power output of 10 MW. The submarine is designed to carry enough nuclear fuel to power the submarine for 25 years.

Assuming the actual energy released per fission reaction is 168 MeV, calculate the mass of $^{235}_{92}U$ that needs to be carried by USS Nautilus to achieve this.

mass of $^{235}_{92}U$ = ... kg [3]

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(vii) The fission reaction involving $^{235}_{92}U$ is effective as it is a type of nuclear chain reaction. Suggest why the reaction is considered a *chain reaction*.

.....

..... [1]

(viii) State one advantage and one disadvantage in the use of nuclear power instead of diesel-electric power in providing energy for the submarine.

Advantage:

.....

..... [1]

Disadvantage:

.....

..... [1]

(b) In a sample of naturally occurring uranium, the isotope $^{238}_{92}U$, which has a half-life of 4.47×10^9 years, undergoes radioactive decay to form $^{206}_{82}Pb$.

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + \text{other decay products}$$

(i) Define *half-life*.

.....

..... [1]

(ii) Besides $^{206}_{82}Pb$, the other decay products formed consist of alpha and beta particles. Determine the number of alpha and beta particles formed when one $^{238}_{92}U$ isotope decays to form $^{206}_{82}Pb$.

number of alpha particles = ...

number of beta particles = ... [2]

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(iii) A sample of naturally occurring uranium contains 120 kg of $^{238}_{92}U$ after some of the isotopes have decayed to $^{206}_{82}Pb$. Given that the original mass of $^{238}_{92}U$ in the sample was 200 kg, determine the age of the sample.

age of sample = ... years [2]

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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS

9749/04

Paper 4 Practical

24 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: Will be announced by invigilator

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and the laboratory where appropriate in the boxes provided on the right.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

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1	
2	
3	
4	
Total	

This document consists of **17** printed pages.

[Turn over

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1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100 g of salt as shown in Fig. 1.1.

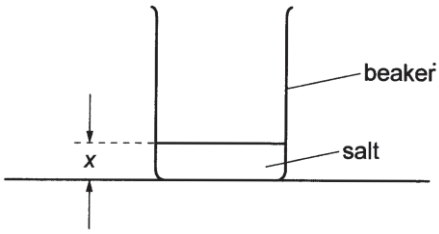

Fig. 1.1

(i) Measure and record the depth x of salt in beaker **P** using the vernier calipers.

x = ... [1]

(ii) Estimate the percentage uncertainty in your value of x.

percentage uncertainty = ... [1]

(b) You have been provided with two cards. Each card has a hole of a different size.

(i) Measure and record the diameter d of the smaller hole.

d = ... [1]

(ii) Determine the area A of the smaller hole.

A = ... [1]

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(c) **(i)** Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

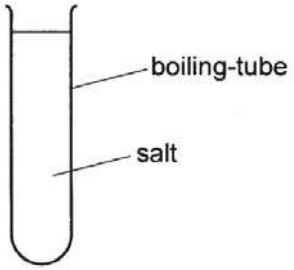

Fig. 1.2

(ii) Cover the open end of the boiling-tube with the card that has the smaller hole.

Use tape to attach the card to the boiling-tube.

The hole should not be covered by tape. When the boiling-tube is inverted, it should not be possible for salt to leave the boiling-tube other than through the hole.

(iii) Cover the hole with your finger.

Invert the boiling-tube over the empty beaker **Q**.

Remove your finger and allow the salt to flow through the hole into beaker **Q** for two minutes.

It may be necessary to shake the boiling-tube gently to achieve constant flow.

(iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level.

Measure and record the depth *y* of salt in beaker **Q**.

y = ...

(v) Estimate the mass *m* of salt in beaker **Q**.

m = ... [1]

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(d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker, with a hole the same size as that in **(c)(ii)**, should be inverted to apply 5 g of salt to food.

time = ... [1]

(e) It is suggested that the rate of flow R of salt is proportional to the area A of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion. Present your measurements and calculated results clearly.

.....

.....

.....

.....

.....

.....

.....

..... [6]

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(f) A statement found on the internet says that:

"The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However there is no manufacturing standard."

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 15 marks]

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You may not need to use all of the materials provided.

2 In this question you will investigate how the light detected by a light-dependent resistor (LDR) depends on the thickness of an absorber.

(a) (i) Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

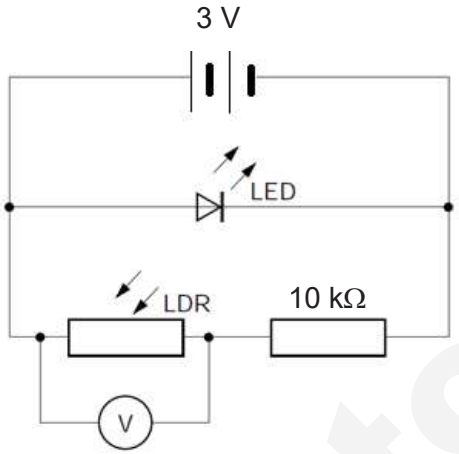

Fig. 2.1

(ii) Use the black paper and the Sellotape to make a cylinder of length 4 cm. The cylinder should fit neatly over the LDR.

(iii) Cut the cylinder in half so that you have two cylinders of length 2 cm.

(iv) Tape one cylinder over the LDR and the other cylinder over the LED as shown in Fig. 2.2.

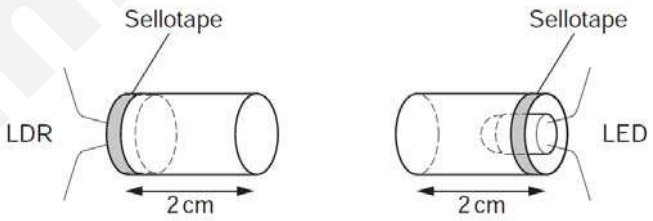

Fig. 2.2

(b) Place the cylinders together, as shown in Fig. 2.3. Record the voltmeter reading V_0.

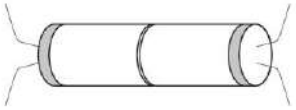

Fig. 2.3

V_0 = ... [1]

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(c) Fold the sheet of tracing paper in half four times so that you have 16 layers.

(i) Measure the thickness of these 16 layers.

thickness of 16 layers = ... [1]

(ii) Estimate the percentage uncertainty in this measurement. Show your working.

percentage uncertainty = ... [1]

(iii) Determine the thickness t of one layer of tracing paper.

t = ... [1]

(iv) Justify the number of significant figures you have given for t.

.....

.....

.....

..... [1]

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(d) **(i)** Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4. Record the voltmeter reading V.

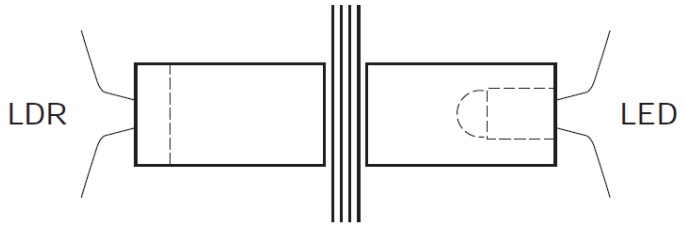

Fig. 2.4

V = ...

(ii) Repeat **(d)(i)** using eight layers of tracing paper.

V = ... [1]

(e) Explain whether your results support the idea that $V - V_0$ is proportional to the number of layers n of tracing paper.

.....

.....

.....

.....

.....

..... [2]

[Total: 8 marks]

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You may not need to use all of the materials provided.

3 In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.

(a) (i) Set up the apparatus as shown in Fig. 3.1.

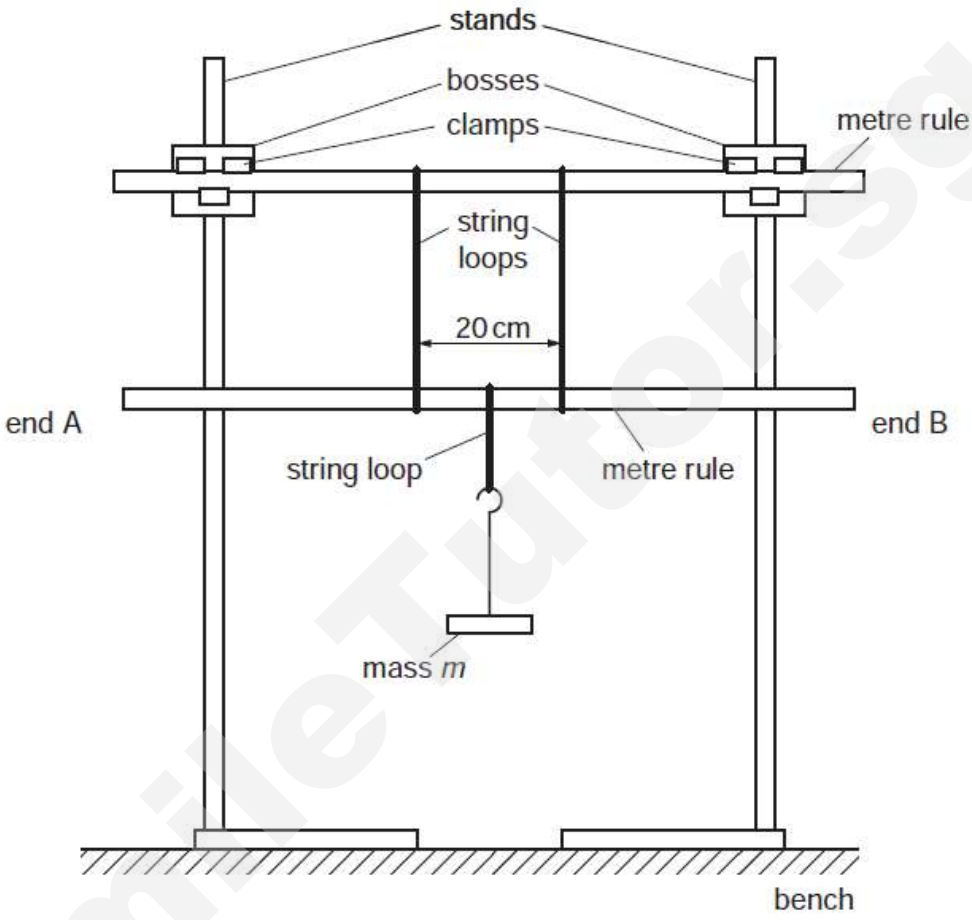

Fig. 3.1

Slide the two loops of string onto a rule and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench.

Using the string provided, make a loop of circumference 20 cm. Slide this shorter loop onto the second rule and use the longer loops to support this second rule.

Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

Use the shorter loop of string to suspend a mass m at the 50 cm mark on the second rule, where m = 0.500 kg.

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(ii) Move the end A of the lower rule towards you and the end B away from you.
Release the rule and watch the movement.
End A will move away from you and back towards you, completing a swing.
The time taken for one complete swing is T.
Determine an accurate value for T.

T = ... [1]

(b) Change m and repeat **(a)(ii)** until you have six sets of values of m and T.

[7]

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(c) The quantities m and T are related by the equation

$$\frac{1}{T^2} = P\ m + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.

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P = ...

Q = ... [4]

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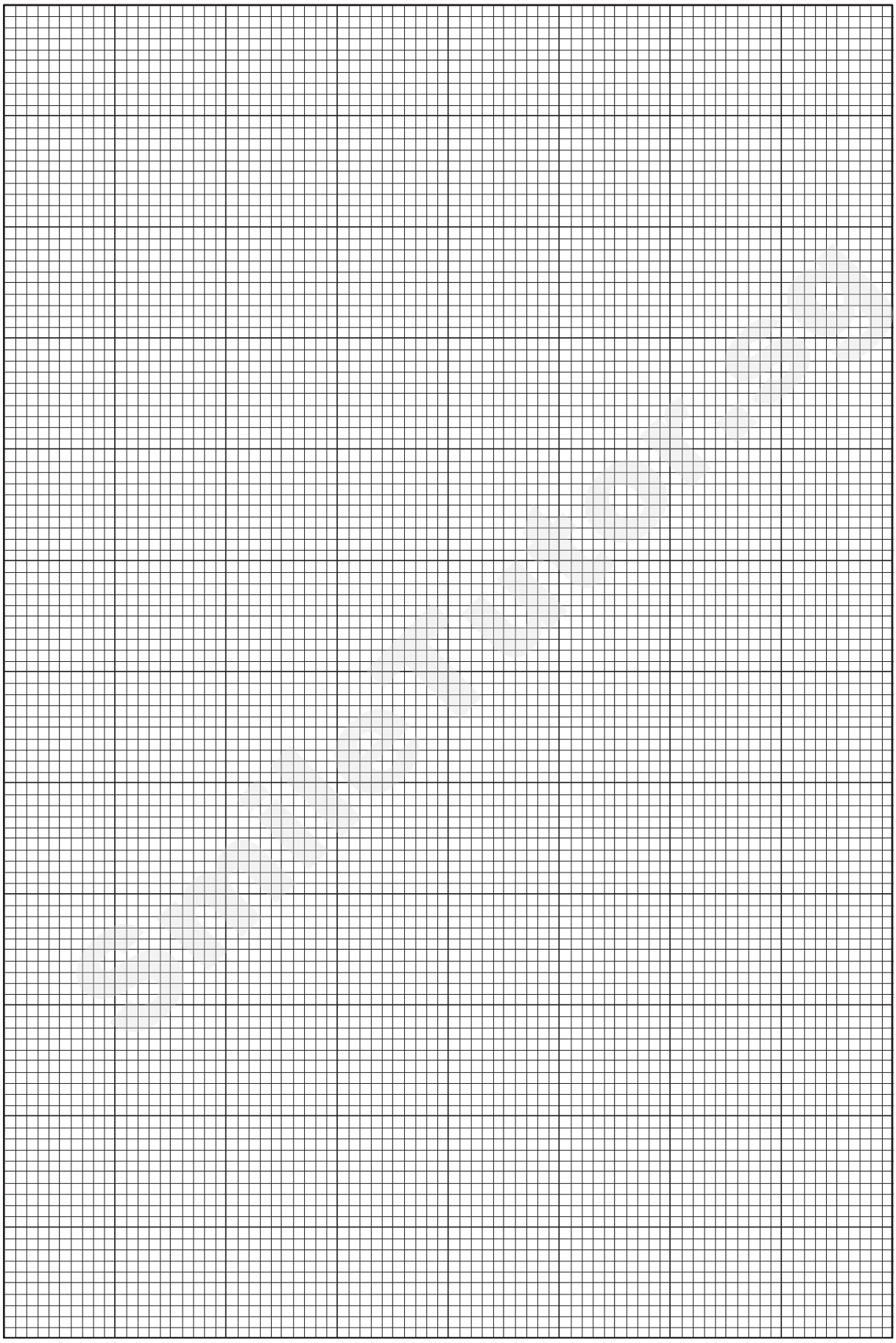

[3]

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(d) Comment on any anomalous data or results that you may have obtained.

.....

.....

..... [1]

(e) State two significant sources of errors in this experiment.

1 .....

.....

.....

2 .....

.....

..... [2]

(f) Suggest improvements that could be made to the experiment to address the sources of error identified in **(e)**. You may suggest the use of other apparatus or different procedures.

1 .....

.....

.....

2 .....

.....

..... [2]

[Total: 20 marks]

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4 A student is investigating the motion of magnets falling through a vertical copper pipe as shown in Fig. 4.1.

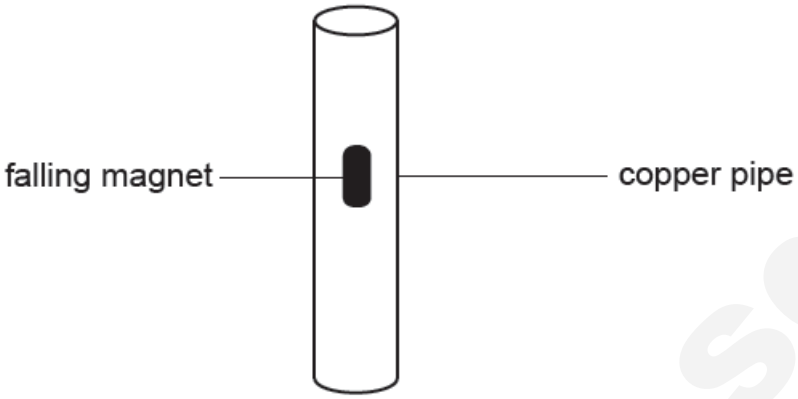

Fig. 4.1

The student releases a magnet above the copper pipe. The magnet has speed v as it leaves the pipe.

It is suggested that the relationship between v and B is

$$v = v_o e^{-\lambda B}$$

where B is the magnetic flux density at the poles of the magnet and v_o and λ are constants.

Design a laboratory experiment to test the relationship between v and B. Explain how your results could be used to determine values of v_o and λ. You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

Diagram

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[Total: 12 marks]

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

SOLUTION

PHYSICS

9749/01

Paper 1 Multiple Choice

26 September 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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1	2	3	4	5	6	7	8	9	10
D	D	D	A	B	C	D	A	D	A
11	12	13	14	15	16	17	18	19	20
B	B	D	D	B	D	D	A	D	B
21	22	23	24	25	26	27	28	29	30
C	D	C	A	A	D	D	A	C	B

1 A body, dropped from the edge of a cliff, is timed to take (2.0 $\pm$ 0.1) s to fall to the surface of the sea. If the acceleration of free fall is taken to be (9.8 $\pm$ 0.2) m s^{-2}, the calculated height of the cliff above the water surface should be quoted as

A (20 $\pm$ 0.1) m

B (20 $\pm$ 0.2) m

C (20 $\pm$ 1) m

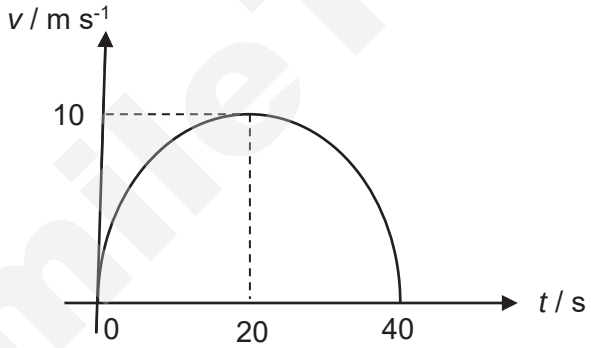
D (20 $\pm$ 2) m

Ans: **D**

$s = ut + 1/2at^2 = 1/2at^2$

$$\frac{\Delta s}{s} = \frac{\Delta a}{a} + 2\frac{\Delta t}{t}$$

2 The velocity-time graph below depicts the motion of an object travelling in a straight line. Which of the following statements is true?



A During the first 20 s of the motion, the object accelerates and travels a distance of 200 m.

B The acceleration of the object increases during the first 20 s to become a maximum when the velocity is 10 m s^{-1}.

C The acceleration of the object when t = 5 s is equal to its acceleration when t = 35 s.

D The object decelerates during the final 20 s of its motion, with the greatest deceleration occuring at t = 40 s.

Ans: **D**

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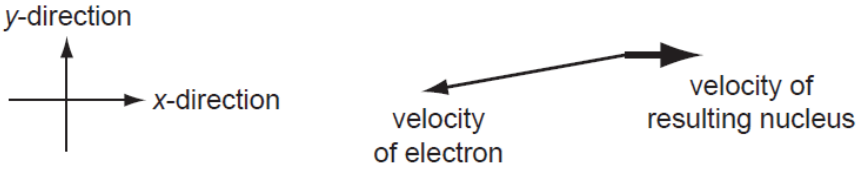
3 A stationary nucleus undergoes beta-decay. The diagram below shows the velocities of the resulting nucleus and the emitted electron.



How does the diagram support the idea that a unseen third particle is also emitted?

A If there were only two particles involved, their velocities should be equal and opposite.

B It is clear that linear momentum is not conserved in the x-direction.

C Something must carry away the extra energy.

D The linear momentum of the original nucleus has no y-component.

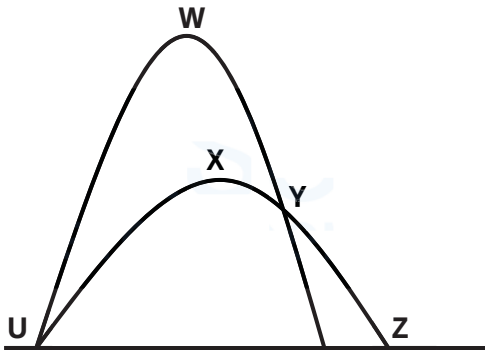
Ans: **D**
A is incorrect; their MOMENTA would be equal and opposite. The velocity of the electron would be expected to be higher than that of the resulting nucleus, as the mass of an electron is very much smaller than that of a nucleon.

B is incorrect; momentum is the product of mass and velocity. Only velocity is shown in the diagram.

C is incorrect; the concept of energy cannot be shown on a vector diagram.

D is correct; the original nucleus was stationary thus had no y-component of linear momentum. The electron has a y-component for its momentum but the resulting nucleus does not have a y-component for its momentum. The total momentum after the decay must be zero thus there must be a third particle.

4 The paths of two identical projectiles, fired with the same initial speed but with different launch angles, are shown below. Which of the following statements is true?



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A The kinetic energies of both projectiles are the same at Y if there is no air resistance.

B The potential energy of the projectile at W is lower than the potential energy of the projectile at X.

C The kinetic energy of the projectile at W and the kinetic energy of the projectile at X are both zero.

D The kinetic energy of the projectile at W is higher than the kinetic energy of the projectile at X.

Ans: **A**
Using conservation of energy, with same initial KE, at D where the GPE is the same, they must have the same KE.

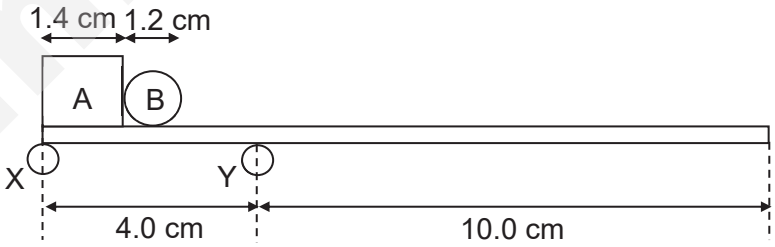
5 A tractor of mass 1000 kg pulls a trailer of mass 1000 kg via a tow-bar. The total resistance to motion has a constant value of 4000 N. One quarter of this resistance acts on the trailer. At first the acceleration of the tractor and trailer is 2.0 m s^{-2} but eventually they move at a constant speed of 6.0 m s^{-1}.

What is the force exerted on the tractor by the tow-bar when the acceleration of the tractor and trailer is 2.0 m s^{-2}?

A 1000 N **B** 3000 N **C** 5000 N **D** 8000 N

Ans: **B**
For the trailer, ΣF = ma
Tensile force – 1000 = 1000 (2.0)
Tensile force = 2000 + 1000 = 3000 N

6 A beam of negligible mass is supported by two rods X and Y. Block A of mass 200 g and ball B of mass 100 g rest on the beam as shown. Both A and B have uniform density.



If ball B were to start rolling to the right, what is the distance it would have moved before the beam just loses contact with rod X? Assume that there is negligible friction.

A 6.6 cm **B** 8.0 cm **C** 8.6 cm **D** 9.4 cm

Ans: **C**

For losing contact, taking moments about pivot at Y,
Clockwise moment = anticlockwise moment
(0.100)(g)x = (0.200)(g)(3.3 cm)
x = 6.6 cm. (from Y)
distance moved = 10.6 – 2.0 = 8.6 cm

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7 A submarine descends vertically at a constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight. Which of the following relationships between the magnitudes of these three forces is correct?

A weight < drag

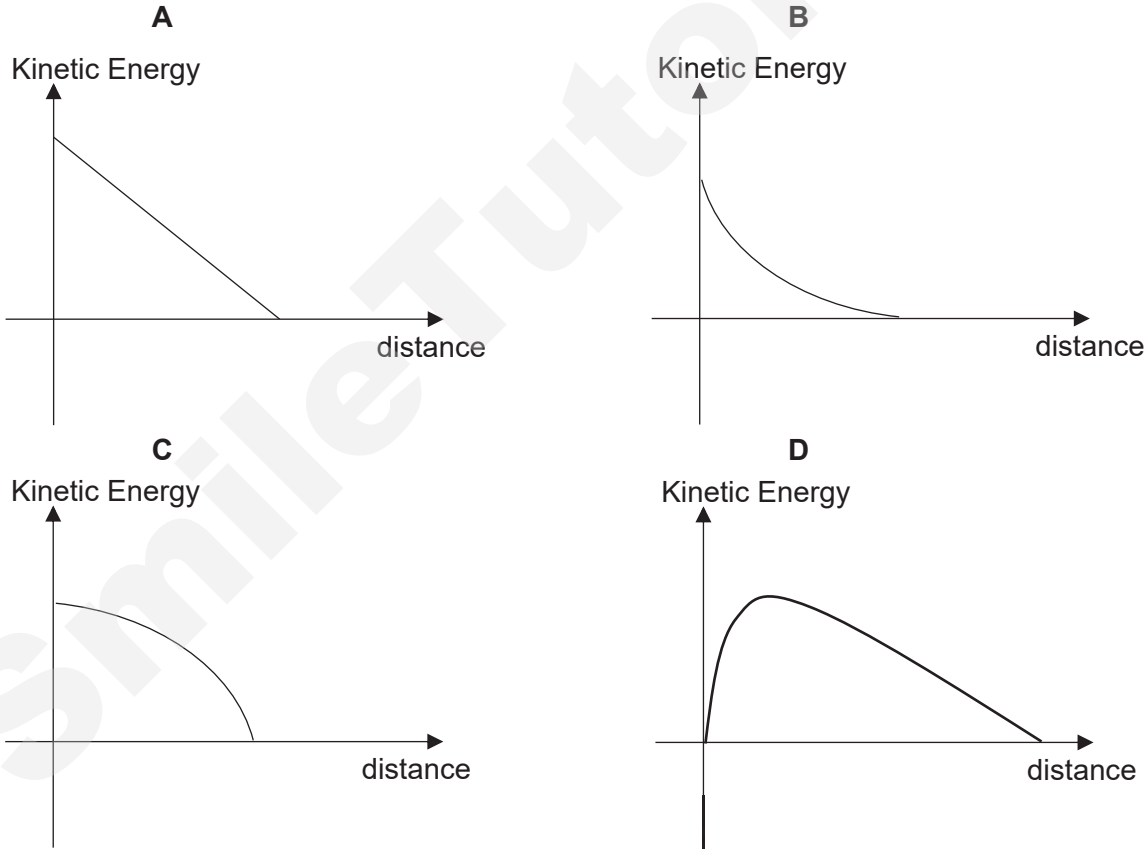
B weight = drag

C weight < upthrust

D weight > upthrust

Ans: **D**
Submarine is descending, so Σ F = W – U – D = 0 (downwards positive)
A to C options are not possible.

8 A block is projected at a certain speed up a frictionless slope. Which of the following graphs correctly shows the relationship between the kinetic energy of the block and the distance travelled by the block after its point of projection?



Ans: **A**

Kinetic energy = ½ mv^2
Consider $v^2 = u^2 + 2as$
In this case a = g sinθ, which is a constant, and in opposite direction to initial velocity (up-slope)

$v^2 = u^2 – 2$ (g sin θ)s
½ m v^2 = – m (g sin θ) s + ½ m u^2

Hence
Kinetic energy = – m (g sin θ) s + ½ m u^2
Which is a straight line graph with negative gradient and a positive y-intercept.

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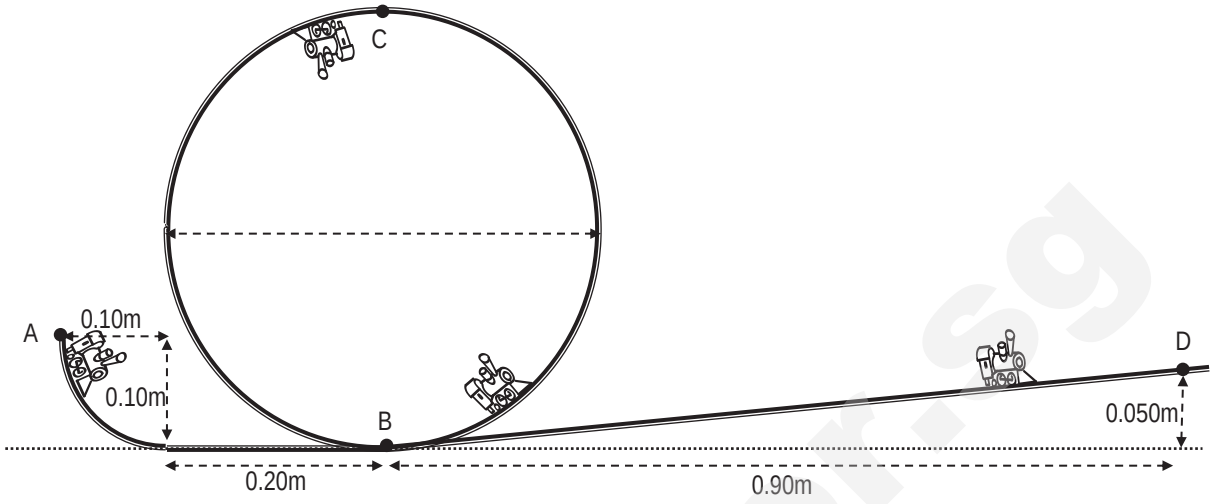
9 A toy train of mass *m* passes point **A** of the track with velocity *v*. What is the minimum value of *v* such that the train will travel up the loop of radius 0.20 m via points **B**, then **C** and eventually reach point **D**? You may ignore resistive forces in your calculation.



A 1.0 m s^{-1} **B** 1.4 m s^{-1} **C** 2.4 m s^{-1} **D** 2.8 m s^{-1}

Ans: **D**

In order to reach D, train must at least have enough energy to reach the highest point C with min K.E to remain in contact with the loop. Therefore K.E initially required to have at A would be the additional P.E. + ½ m v_C^2 needed.

mg (h_C - h_A) + ½ m v_C^2 = ½ m v_A^2

$\frac{mv_C^2}{R} = mg$

v_A = 2.8 ms^{-1}

10 What is the speed of a geostationary satellite that is orbiting Earth? The mass of Earth is taken to be 6.0 × 10^{24} kg.

A 3.08 × 10^3 m s^{-1} **B** 4.71 × 10^4 m s^{-1} **C** 1.80 × 10^5 m s^{-1} **D** 4.23 × 10^7 m s^{-1}

Ans: **A**

$$\frac{GM_E m}{r_A^2} = \frac{mv^2}{r_A}$$

$$v^2 = \frac{GM_E}{r_A}$$

And since $v = r\frac{2\pi}{T}$

$$\frac{1}{r} = \frac{2\pi}{vT}$$

Therefore, $v^3 = \frac{GM_E 2\pi}{T}$

v = 3080 m s^{-1}

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11 A ball which is thrown upward near the surface of Earth with velocity v will come to rest five seconds later. If the ball were to be thrown upward with the same velocity v on Planet X, it would still be moving upward at 31 m s^{-1} after five seconds.

What is the ratio $\frac{\text{gravitational field strength near surface of Planet X}}{\text{gravitational field strength near surface of Earth}}$?

A 0.16 **B** 0.37 **C** 0.53 **D** 0.63

Ans: **B**
On earth, $v = u + g_e t$
$u = 49.05\ ms^{-1}$
With the same speed,
On planet, $v = u + g_p t$
$g_p = 3.61\ ms^{-2}$
ratio will be 0.37

12 Which of the following statements is *not true* for an oscillating body when light damping is present?

A The damping force is always in the opposite direction to the velocity of the body.

B The damping force is always in the opposite direction to the acceleration of the body.

C The presence of light damping changes the period of oscillation.

D The presence of light damping changes the maximum potential energy of the body.

Ans: **B**
A and D is true. C is true only for some cases and hence not true for some cases. As C is not *not true* for all cases it is not the answer. B is always not true because the damping force can be in the same direction as the acceleration of the body.

13 A fixed mass of ideal gas in a thermally insulated container is compressed. After compression, the temperature of the gas would have

A fallen, since more molecules bombard the container so they must be moving slower.

B fallen, since the molecules collide more frequently with each other so their average speed is slower.

C remained constant if the compression is very slow.

D risen, since doing work on the gas increases the kinetic energy of the gas molecules.

Ans: **D**

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14 Two vessels X and Y, of volumes V_X and V_Y respectively, are kept at temperatures T_X and T_Y. They are filled with the same ideal gas and are connected via a narrow tube.

What is the ratio $\frac{\text{number of molecules in X}}{\text{number of molecules in Y}}$?

A $\frac{T_X V_X}{T_Y V_Y}$ **B** $\frac{T_X V_Y}{T_Y V_X}$ **C** $\frac{T_Y V_Y}{T_X V_X}$ **D** $\frac{T_Y V_X}{T_X V_Y}$

Ans: **D**

For ideal gas, $pV = nRT$

$n = \frac{pV}{RT}$

since X and Y are filled with the same gas

$$\frac{\text{number of molecules in X}}{\text{number of molecules in Y}} = \frac{\text{number of moles of gas in X}}{\text{number of moles of gas in Y}}$$

$$= \frac{\frac{p_X V_X}{RT_X}}{\frac{p_Y V_Y}{RT_Y}}$$

$$= \frac{\frac{V_X}{T_X}}{\frac{V_Y}{T_Y}}$$ since the pressure of both containers is the same

$$= \frac{T_Y V_X}{T_X V_Y}$$

15 A potential difference is applied between the electrodes of a gas discharge tube of area 1.3×10^{-3} m^2 so that the gas is ionised into positively charged particles and electrons.

The gas carries a current of 12.2 mA and the number of electrons passing any point in the gas per unit time is 2.54×10^{16} s^{-1}. Given that the charge on each positively charged particle is 3.20×10^{-19} C and the number of the positively charged particles per unit volume is 1.0×10^{19} m^{-3}, what is the drift velocity of these positively charged particles in the gas?

A 0.98 m s^{-1} **B** 1.96 m s^{-1} **C** 3.91 m s^{-1} **D** 7.82 m s^{-1}

Ans: **B**

$$I = \frac{Nq_-}{t} + nAq_+v$$

$$12.2 \times 10^{-3} = 2.54 \times 10^{16} \times 1.6 \times 10^{-19} + 10^{19} \times 1.3 \times 10^{-3} \times 3.2 \times 10^{-19} v$$

$$v = 1.96 \text{ m } s^{-1}$$

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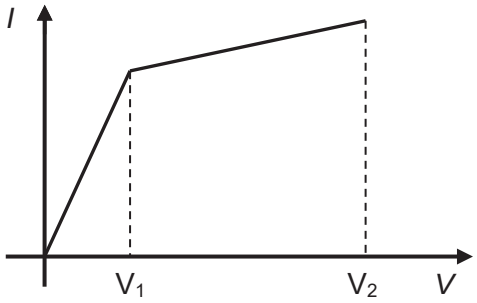
16 The graph below shows the variation of current *I* through an electrical component with the potential difference *V* across the component.



The resistance of the component is

A constant from 0 to V_1, then increases to another constant from V_1 to V_2.

B constant from 0 to V_1, then decreases to another constant from V_1 to V_2.

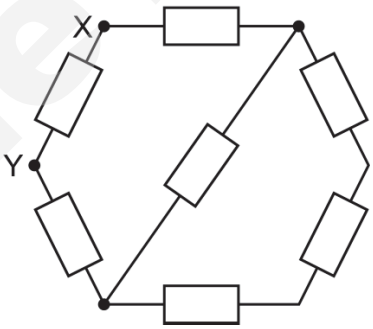
C constant from 0 to V_1, then decreases continuously from V_1 to V_2.

D constant from 0 to V_1, then increases continuously from V_1 to V_2.

Ans: **D**

From V_1 to V_2, the ratio I/V decreases. Since R = V/I, the resistance increases.

17 The diagram shows a network of 7 resistors, each with resistance *R*.



What is the resistance between points X and Y?

A $\frac{2}{3}R$ **B** $\frac{3}{5}R$ **C** $\frac{7}{11}R$ **D** $\frac{11}{15}R$

Ans: **D**

$$(R_{XY})^{-1} = \left(R + \frac{3R \times R}{3R + R} + R\right)^{-1} + R^{-1}$$

$$R_{XY} = \frac{11}{15}R$$

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18 In a transverse progressive wave with a period of 0.060 s, the least distance between two adjacent points which have a phase difference of 90° is 0.20 m. What is the time taken for the wave to travel a distance of 4.00 m?

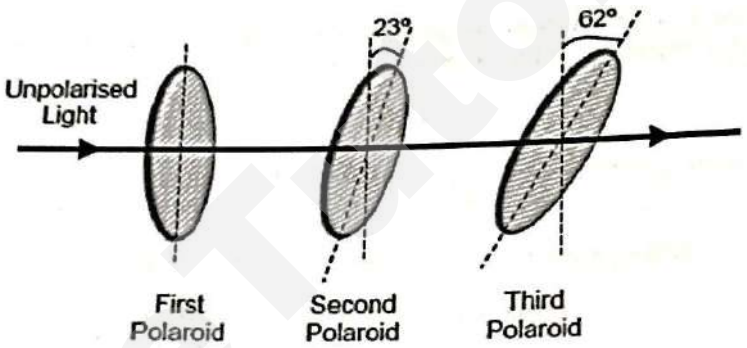
A 0.30 s **B** 0.60 s **C** 1.20 s **D** 1.50 s

Ans: **A**

The wavelength of the progressive wave is $4 \times 0.20 = 0.80$ m
Speed of the wave = $\frac{\lambda}{T} = \frac{0.80}{0.060} = 13.3\ m\ s^{-1}$

Time taken to travel 4.00m = $\frac{4.00}{13.3} = 0.30\ s$

19 Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at 23° and 62° respectively to that of the first polaroid, as shown in the diagram below.



When unpolarised light of amplitude A_o is incident on the stack of polaroids, its amplitude after passing through the first polaroid is A_1, and becomes A_2 after it passes through the second polaroid, and subsequently A_3 after it passes through the third polaroid. What is the value of $\frac{A_3}{A_1}$?

A 0.25 **B** 0.31 **C** 0.43 **D** 0.72

Ans: **D**

By Malus Law,
$A_3 = [\cos(62^o - 23^o)] \times \cos 23^o \times A_1 = 0.72\ A_1$

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20 A space shuttle orbits at a height of 330 km above the surface of the Earth. It carries two panels separated by a distance of 24 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the panels with a telescope that has an aperture diameter of 85 mm. Assume that the panels act as point sources of light for the observer. Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
A	Yes	5.9×10^{-6}
B	Yes	7.3×10^{-5}
C	No	5.9×10^{-6}
D	No	7.3×10^{-5}

Ans: **B**

$S = r\theta$

$\theta = s/r = 24/330\,000 = 7.3 \times 10^{-5}$

Min resolution = $\lambda/b = 5.9 \times 10^{-6}$ rad

21 A single slit that is 1.0 mm wide is illuminated by light which has a wavelength of 450 nm. What is the width of the central maximum in the diffraction pattern produced on a screen 5.0 m away?

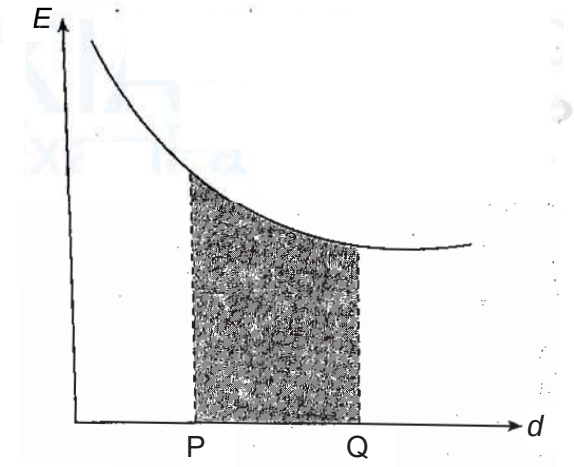
A 1.1 mm **B** 2.2 mm **C** 4.5 mm **D** 7.2 mm

Ans: **C**

$\sin\theta = \lambda/b$

$s = 2r\theta = 4.5$ mm

22 The graph below shows the variation of the electric field strength *E* with distance *d* along a straight line in an electric field. What does the shaded area under the curve between P and Q represent?



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A The work done by the electric field to move a charge from P to Q.

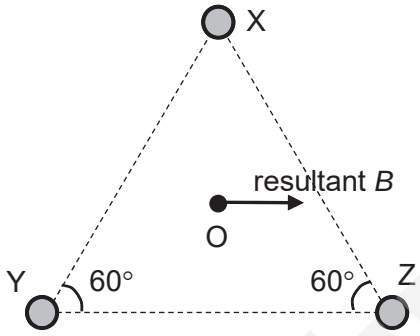
B The total charge that moves between P and Q.

C The power dissipated when moving a unit charge from P to Q.

D The potential difference between P and Q.

Ans: **D**

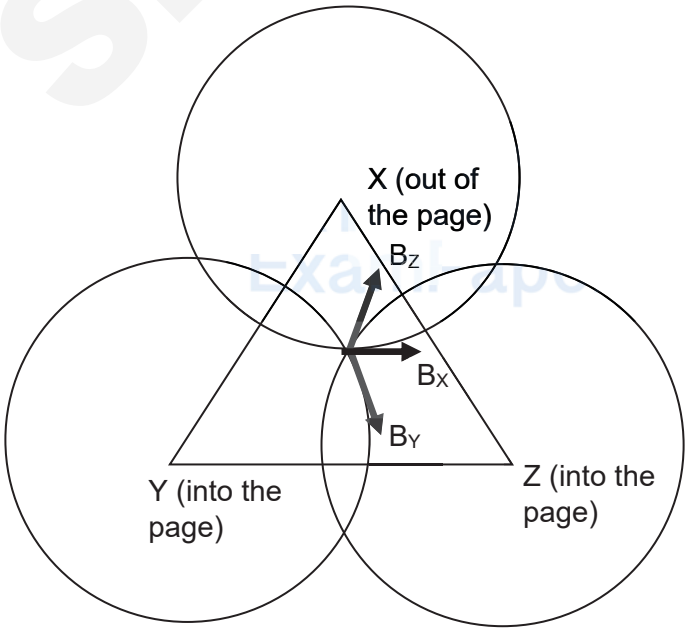
23 Three parallel conductors, all carrying currents of the same magnitude, pass vertically through the three corners X, Y and Z of a horizontal equilateral triangle as shown in the diagram below. A resultant magnetic flux density *B* acts at the centre O of the triangle, in the direction as shown below. What must be the directions of the currents in X, Y and Z?



	Into the page	Out of the page
A	X	Y and Z
B	Z	X and Y
C	Y and Z	X
D	X, Y and Z	None

Ans: **C**

For the resultant flux density at O to be as shown, the directions of B_X, B_Y and B_Z must be as shown in diagram below. Using the Right Hand Grip Rule, the corresponding direction of current can be found.



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24 An electron moves along the axis of a solenoid carrying current. Which of the following is a correct statement about the electromagnetic force acting on the electron?

A No force acts.

B The force acts in the direction of motion.

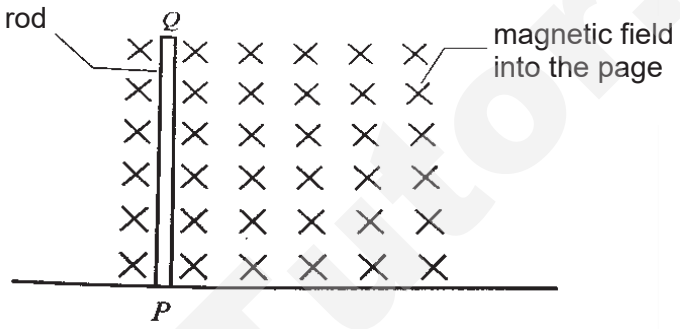
C The force acts against the direction of motion.

D The force acts radially outward towards the solenoid.

Ans: **A**

Since the magnetic flux density acts along the same axis as the current, no electromagnetic force will be experienced by the electron.

25 A vertical rod PQ is hinged to a flat surface at the end P and placed in a uniform magnetic field that acts into the page, as shown in the diagram. When the rod is lightly pushed to the right at the end Q, it swings downwards while still hinged at P.



Just before the end Q hits the flat surface, which of the following statements is correct?

A Q is at a higher electrical potential than P.

B An upward magnetic force acts on the rod.

C An induced current flows to Q from P

D The rod rotates clockwise with a constant angular speed.

Ans: **A**

By Fleming's left hand rule, the electrons in the rod will accumulate at P, causing Q to be of higher electrical potential.

26 A steady current *I* dissipates a certain power in a variable resistor, set at 12 Ω. To dissipate the same power when a sinusoidal alternating current is used, the resistor has to be set at 3 Ω. What is the r.m.s. value of the alternating current?

A $\frac{1}{\sqrt{2}}I$ **B** I **C** $\sqrt{2}\,I$ **D** $2\,I$

Ans: **D**

$I^2(12) = I_{rms}^2\,(3)$

$\Rightarrow I_{rms} = 2I$

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27 The four energy levels of the hydrogen atom and their corresponding energy values are

Level	Energy / eV
P	-13.60
Q	-3.40
R	-1.50
S	-0.85

A spectral line of 488 nm could result from an electron transition between levels

A Q and P **B** R and P **C** R and Q **D** S and Q

Ans: **D**
Energy released during electron transition

$$= \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{488\times10^{-9}} = 4.08\times10^{-19}\ \text{J} = 2.55\ \text{eV}$$

28 What is the wavelength of a beam of electrons accelerated through a potential difference of 5200 V?

A 1.7×10^{-11} m **B** 2.4×10^{-10} m **C** 1.4×10^{-7} m **D** 2.8×10^{-6} m

Ans: **A**

$$\frac{1}{2}mv^2 = eV$$

$$v = \sqrt{\frac{2eV}{m}}$$

$$\lambda = \frac{h}{mv}$$

$$= \frac{h}{\sqrt{2emV}} = \frac{6.63\times10^{-34}}{\sqrt{2(1.60\times10^{-19})(9.11\times10^{-31})(5200)}} = 1.7\times10^{-11}\ \text{m}$$

29 The deviation of alpha particles by thin metal foils through angles ranging from 0° to 180° can be explained by

A random motion of alpha particles.

B diffraction of the alpha particles through the metal due to the wave properties of the alpha particles.

C scattering by small but heavy regions of positive charges.

D scattering by the free electrons in the metal foils.

Ans: **C**
This is the observation from Rutherford's alpha particle scattering experiment.

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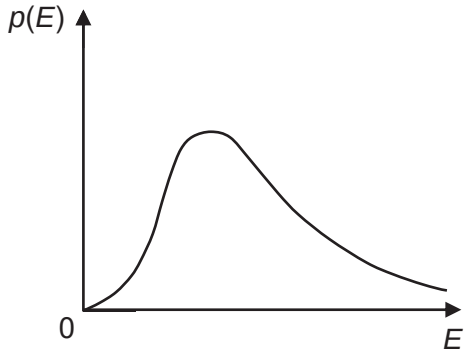
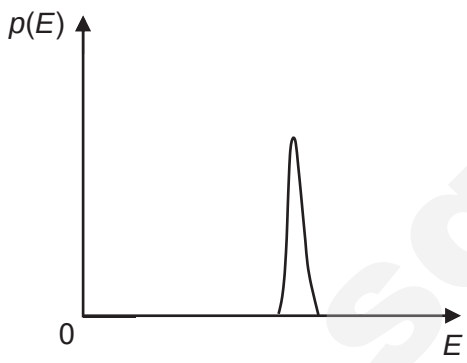
30 Which of the following graphs could represent $p(E)$, the distribution of the energies E of alpha particles that are emitted from a given source?

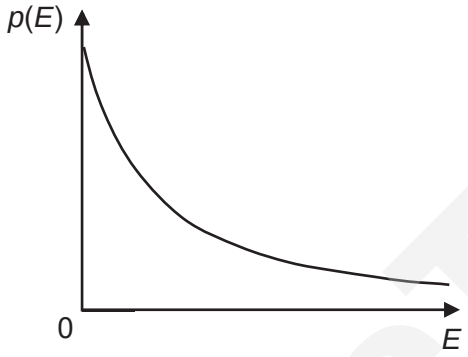
A



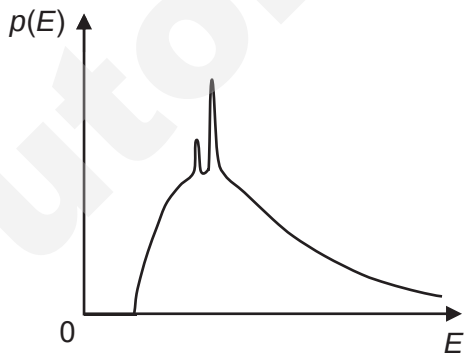
B



C



D



Ans: **B**
The alpha particles emitted from a given source should have a specific value of energy.

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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

CLASS

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PHYSICS 9749/02

Paper 2 Structured Questions

18 September 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **19** printed pages.

[Turn over

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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1 **(a)** State how force is related to linear momentum.

Force is defined as the rate of change of momentum of the body, and the force acts in the direction of the change in momentum. [2]

(b) In a laboratory experiment a small metal cylinder containing liquid carbon dioxide is attached to a trolley as shown in Fig 1.1. The trolley is initially at rest. When the cylinder is punctured, carbon dioxide gas rushes out and the trolley accelerates.

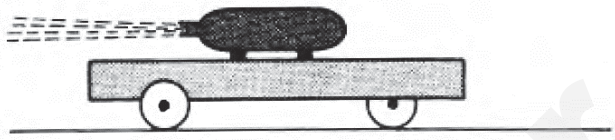

Fig. 1.1

(i) Using Newton's laws of motion, explain the origin of the force that is accelerating the trolley.

N2L: The cylinder exerts a force on the gas, equal to the rate of change of momentum of the gas (The gas rushes out of the cylinder/the cylinder pushes the gas out)

N3L, the gas exerts an equal force on the gas, in the direction opposite that of the escaping gas, causing a forward force on the cylinder – trolley system

N2L: The forward force on the cylinder – trolley system causes its momentum to change (it will accelerate) *OR any link of this forward force to acceleration*

OR mention that no other forces so this causes acceleration [3]

(ii) The trolley and cylinder have a mass of 0.68 kg and they reach a maximum speed of 2.7 m s^{-1}. The total mass of carbon dioxide initially in the cylinder is 12 g.

1. Write an equation relating the initial and final velocities of the trolley-cylinder system in terms of the average acceleration *a* of the trolley-cylinder system, and the time *t* taken for this system to achieve maximum speed.

$v = u + a t$

$2.7 = 0 + a t$

$a = \frac{2.7}{t}$

[1]

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2. Write an equation relating the average ejection speed v_g of the carbon dioxide gas, the average accelerating force F exerted on the gas and the time t taken for all the gas to be ejected.

$$F = \frac{m(v_g - u_g)}{t} = \frac{0.012(v_g - 0)}{t}$$

$$F = \frac{0.012\, v_g}{t}$$

[1]

3. Hence calculate the average ejection speed of the carbon dioxide gas.

$$\Sigma F = M a$$

$$\frac{0.012\, v_g}{t} = 0.68\frac{2.7}{t}$$

$$v_g = 150 \text{ m s}^{-1}$$

average ejection speed = ... m s^{-1} [2]

(iii) The cylinder is then removed from the trolley, and the trolley is given a push so that it collides head-on with a second stationary trolley which is identical to the first one.

Describe the subsequent motion of the trolleys if they make

1. an elastic collision,

The first trolley will stop, the second trolley will move with a velocity of same magnitude and direction as that of the first trolley before collision. [2]

2. a completely inelastic collision.

They will stick together and move in the same direction as before, with a smaller speed than that of the first trolley before collision. [1]

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2 **(a)** **(i)** Define *gravitational potential* at a point in a gravitational field.

Gravitational potential is defined as work done per unit mass by an external agent on the test mass to move from infinity to a point in the gravitational field without a change in kinetic energy.

..... [1]

(ii) Explain why gravitational potential is always negative.

Gravitational potential at infinity defined as zero and since gravitational force is attractive, work done by external agent as object moves from infinity to a point in the gravitational field so potential is negative.

..... [1]

(b) Fig. 2.1 shows the variation of gravitational potential between the surface of Moon and the surface of Earth along the line joining their centres.

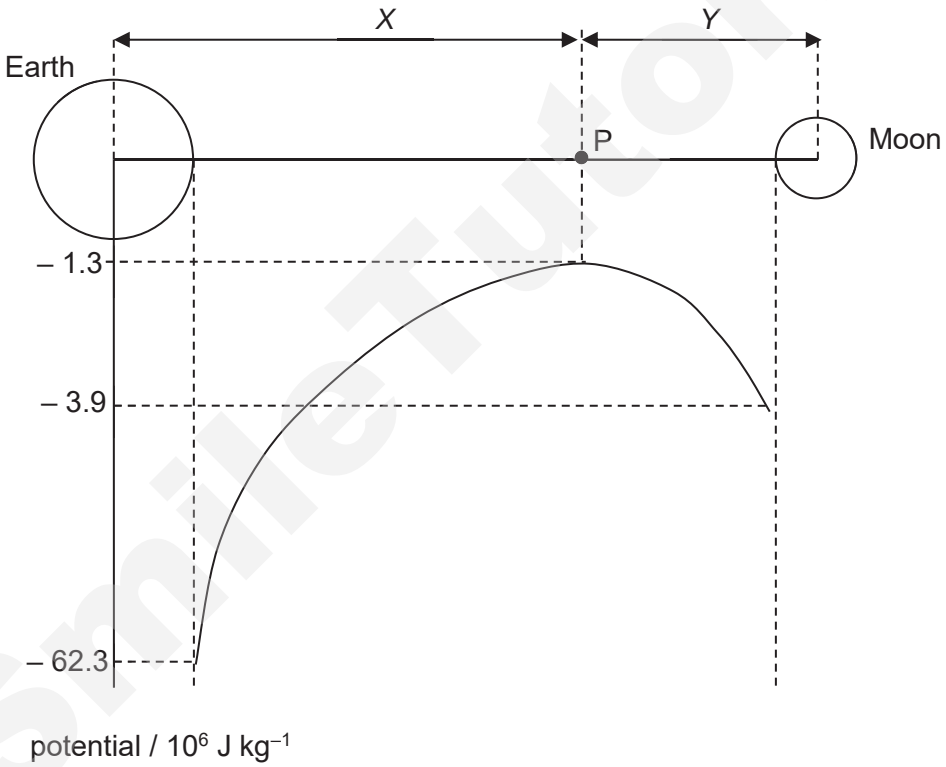

Fig. 2.1

Explain why the gradient of the graph near the surface of Earth and that near the surface of Moon have opposite signs.

The gradient of the potential –displacement graph gives the gravitational field strength, which is a vector, thus, the sign indicates the direction of the gravitational field strength. Near the earth, the net gravitational force is directed towards the earth due to larger influence of earth (larger mass and smaller distance) than moon while near the moon, the net gravitational force is directed towards the moon due to larger influence of moon (smaller distance), their sign are opposite.

..... [2]

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(c) Two moons A and B move in circular orbits about a planet, as illustrated in Fig. 2.2.

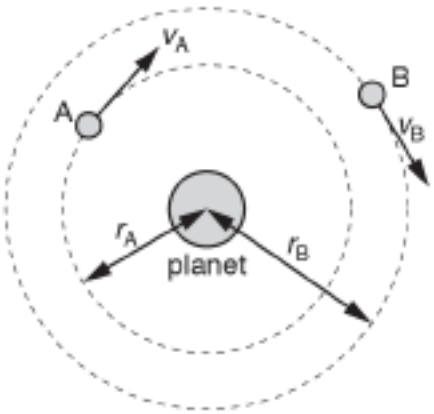

Fig. 2.2

Moon A has an orbital radius r_A of 1.3×10^8 m, linear speed v_A and orbital period T_A.
Moon B has an orbital radius r_B of 2.2×10^{10} m, linear speed v_B and orbital period T_B.

(i) Determine the ratio

1. $\frac{v_A}{v_B}$, and

Since the gravitational force the planet exert on moon A and B provides the centripetal force for them to rotate about the planet,

$\frac{GM_pM_A}{r_A^2} = \frac{M_Av_A^2}{r_A}$

$\frac{GM_p}{r_A} = \frac{v_A^2}{1}$

Since GM_P are constant, $v_A^2 \propto 1/r$

$v_A / v_B = (r_B / r_A)^{1/2}$
$= (2.2 \times 10^{10} / 1.3 \times 10^8)^{1/2}$
$= 13\ (13.0)$

ratio = ... [3]

2. $\frac{T_A}{T_B}$.

$v = 2\pi r / T$
$v \propto r / T$
$T_A / T_B = (r_A / r_B) \times (v_B / v_A)$
$= (1.3 \times 10^8 / 2.2 \times 10^{10}) \times (1 / 13)$
$= 4.5\ (4.54) \times 10^{-4}$

ratio = ... [1]

(ii) The planet spins about its own axis with angular speed 1.7×10^{-4} rad s^{-1}. Moon A is always above the same point on the planet's surface. Determine the orbital period T_B of moon B.

$T = 2\pi / 1.7 \times 10^{-4} = 3.70 \times 10^4$ s
$T_B = 3.70 \times 10^4 / 4.54 \times 10^{-4}$
$= 8.1 \times 10^7$ s

T_B = ... s [2]

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3 At a shooting gallery in a fun fair, a mobile target lion sways horizontally with simple harmonic motion as shown in Fig. 3.1. Hidden in a metal container below the lion target is a motor-driven circular rotating disc with a knob that slides along a frictionless groove attached to the lion. As the disc rotates with constant angular frequency, it pushes the lion target horizontally left and right.

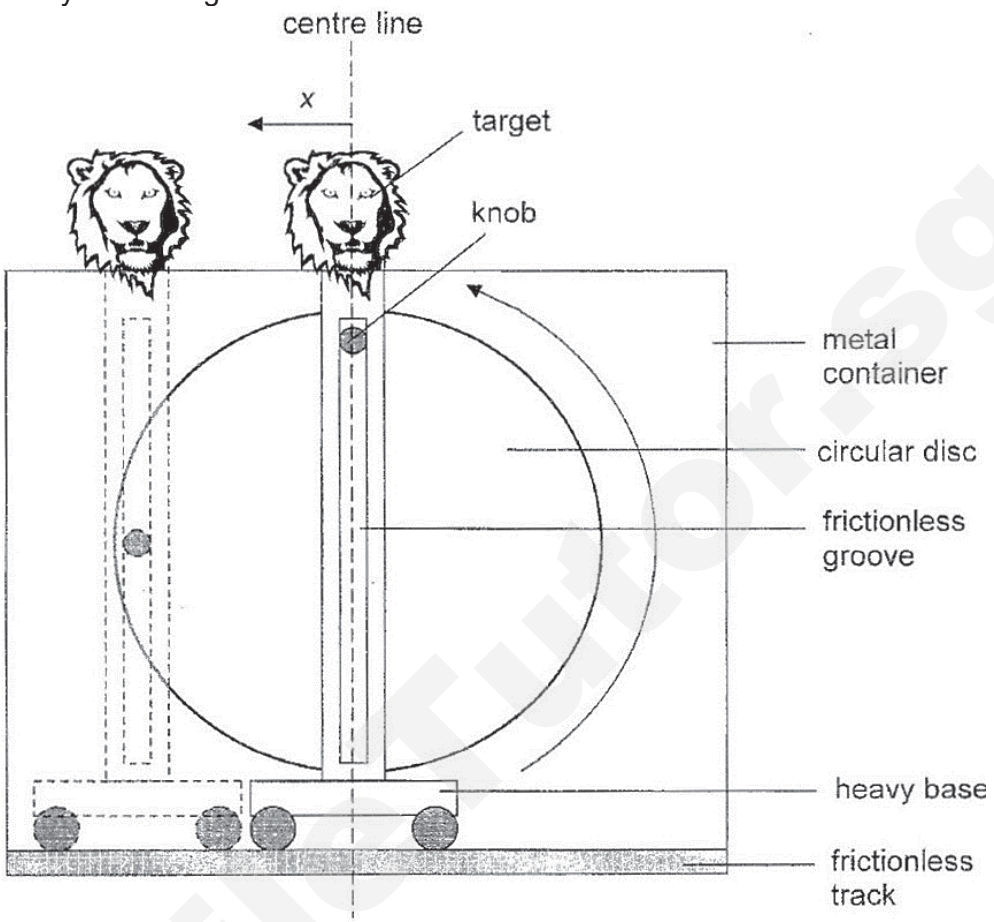

Fig. 3.1

Fig. 3.2 shows how the kinetic energy *KE* of the lion target varies with its displacement *x* from the centre line and Fig. 3.3 shows how its velocity *v* varies with its displacement *x*.

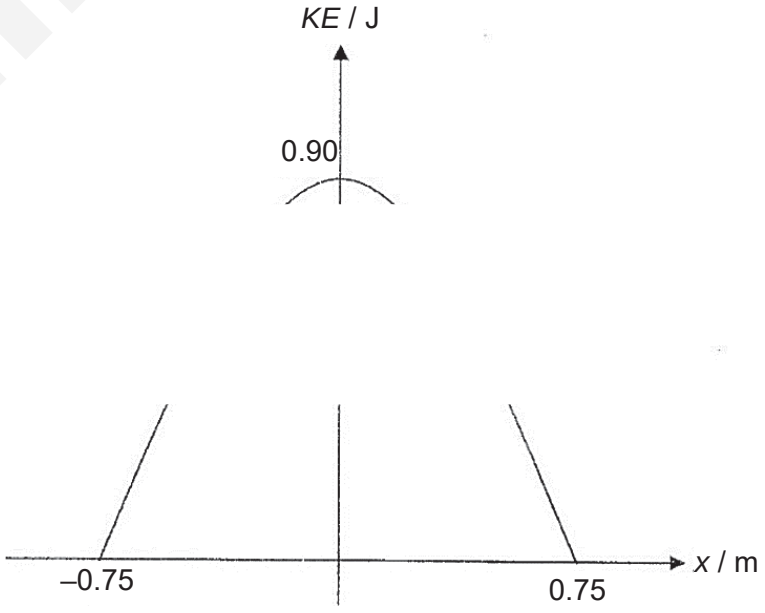

Fig. 3.2

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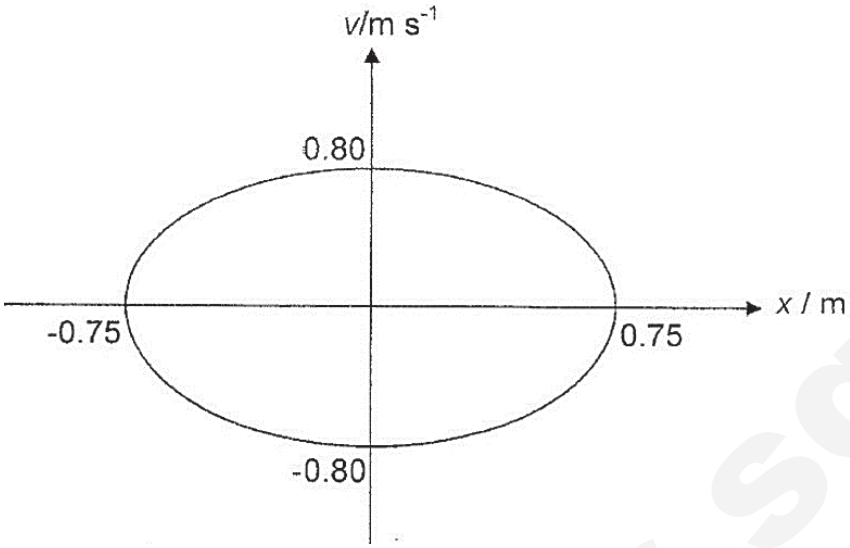

Fig. 3.3

(a) Deduce, from Fig. 3.2 and Fig. 3.3,

(i) the mass of the lion target,

$$KE_{lion,\ max} = \frac{1}{2} m_{lion} v_{lion,\ max}^2$$
$$0.90 = \frac{1}{2}(m_{lion})(0.80)^2$$
$$m_{lion} = 2.81 \text{ kg}$$

mass = ... kg [2]

(ii) the number of revolutions per second of the circular disc,

consider lion,

$$v_0 = \omega_{lion} x_0$$
$$0.80 = 2\pi f (0.75)$$
$$f_{lion} = 0.17 \text{ Hz}$$

Since the disc completes 1 round in the same time as the lion complete 1 oscillation,

$$f_{disc} = f_{lion} = 0.17 \text{ Hz}$$

number of revolutions per second = ... s^{-1} [2]

(iii) the speed of the knob when the displacement of the lion is maximum.

speed of knob is constant regardless of displacement of lion: 0.80 m s^{-1}

speed = ... m s^{-1} [2]

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(b) When the lion target is at its leftmost position, a ball was tossed towards the middle position between the leftmost position and the centre line, with the aim of hitting the lion target. The ball takes 0.74 s to reach that middle position. Determine and explain whether the ball will hit the lion target right at its nose.

$x = x_0 cos(\omega t)$
$\frac{0.75}{2} = 0.75 cos[2\pi(0.17)(t)]$
$t = 0.98\ \text{s}$

Since the target takes 0.98 s to reach the position where the ball is tossed at, the ball does not hit the lion target right at the nose.

Alternatively,
0.74 s is 1/8 of the lion's period. Given that time, the knob moves 45 degrees. However, in order for ball to hit the lion right in the nose, the knob has to move 60 degrees in 0.74 s. Hence the ball does not hit the lion.

4 A positively charged particle passes through a region of uniform magnetic field of flux density 0.75 T, as shown in Fig. 4.1.

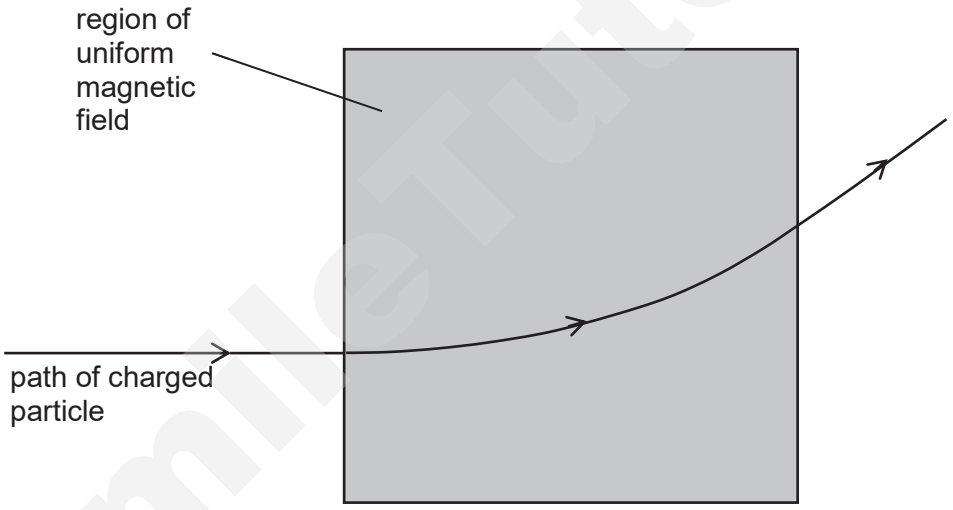

Fig. 4.1

The radius *r* of the path of the particle in the magnetic field is 25 cm.

(a) Define the *tesla*.

One tesla is defined as the magnetic flux density of a magnetic field in which a force per unit length of one newton per metre acts on a conductor which is carrying a current of one ampere in a direction perpendicular to the field.

[2]

(b) State the direction of the magnetic field.

Into the plane of the paper.

[1]

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(c) **(i)** The specific charge of a particle is the ratio of its charge to its mass, $\frac{q}{m}$. Given that the speed of the particle is 9.0×10^6 m s^{-1}, calculate the specific charge of the particle.

When the charged particle enters the magnetic field, the magnetic force acting on it provides the centripetal force for it to undergo circular motion,

$$\Sigma F = ma$$

$$F_B = \frac{mv^2}{r}$$

$$Bqv = \frac{mv^2}{r}$$

$$\frac{q}{m} = \frac{v}{Br}$$

$$= \frac{9.0 \times 10^6}{0.75(25 \times 10^{-2})}$$

$$= 4.8 \times 10^7 \text{ C kg}^{-1}$$

specific charge = ... C kg^{-1} [3]

(ii) Using your answer in **(i)**, suggest the name of a possible charged particle which has entered the uniform magnetic field. Show your working.

Since the elementary charge is 1.60×10^{-19} C and the unified atomic mass unit is 1.66×10^{-27} kg, a ratio of 1 e to 1 u will be

$$\frac{e}{u} = \frac{1.60 \times 10^{-19}}{1.66 \times 10^{-27}} = 9.64 \times 10^7 \text{ C kg}^{-1}$$

Therefore, it can be observed that

$$\frac{q}{m} = 4.8 \times 10^7 = \frac{1}{2}\left(\frac{e}{u}\right)$$

Since the specific charge is 0.5, the charged particle could be an alpha particle (helium-4 nucleus) or hydrogen-2 nucleus (or any other nuclides with a proton-to-neutron ratio of 0.5). ..... [2]

(iii) Explain how the path of the charged particle in the uniform magnetic field will be different if it were an electron projected into the field with the same speed as the positively charged particle in **(i)**.

Upon entering the field, the charged particle will bend downwards instead of upwards. This is so as electron is negatively charged and by Fleming's Left Hand Rule, it can be seen that the magnetic force acting on the electron will be opposite to a positively charged particle. Also, since the specific charge is higher for the electron due to its relatively small mass, the radius of the circular path will be smaller than that of the positively charged particle. .... [2]

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5 **(a)** State Faraday's law of electromagnetic induction.

The induced e.m.f. is proportional to the rate of change of magnetic flux linkage.

.....

.....

..... [1]

(b) Induction heating is commonly used for heating up electrically conductive materials in a clean, efficient and controlled manner. In industry, induction heating is a simple and reliable method for bottle sealing. It welds a circular piece of aluminium foil across the necks of medicine and drink bottles.

As shown in Fig. 5.1, a bottle is first filled at position 1. A plastic cap, complete with a piece of aluminium foil, is applied to the bottle neck at position 2. The foil is also coated with 'hot-melt glue' before being screwed onto the top of the bottle during manufacture. As the bottle passes under the induction heater (positions 3, 4, 5) on the production line, the foil is rapidly heated. The heat generated melts the glue and seals the foil onto the top of the bottle by position 5. When the cap is removed, the foil remains attached, providing an airtight seal and preventing any tampering or contamination of the bottle contents until the customer pierces the foil.

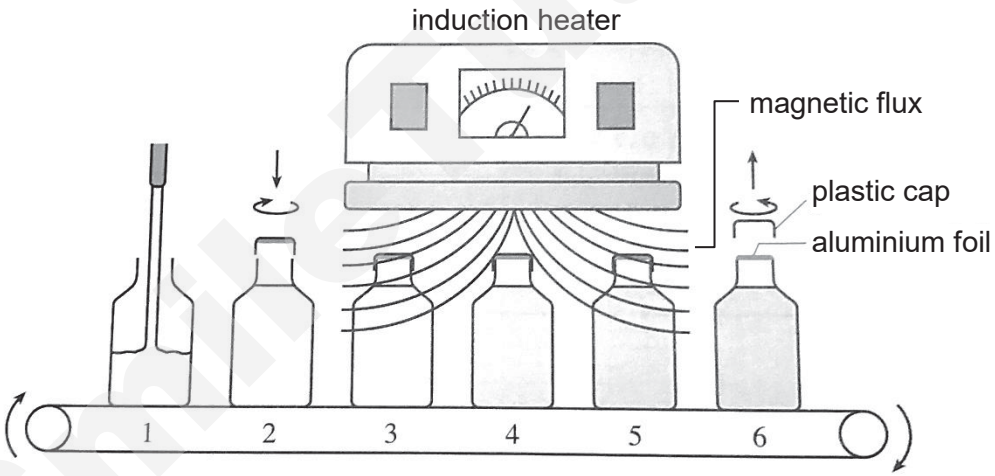

Fig. 5.1

(i) State one advantage of using induction heating.

Any of the following:

.....

The heating process is contact-free, avoiding contamination.

.....

More efficient compared to conduction heating or manually attaching the seals

..... [1]

Minimise contact with hot surfaces: reduces chance of injury

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(ii) Using laws of electromagnetic induction where appropriate, explain how the glue is melted.

Source of B field: There is an **alternating current in the** induction heater, which produces the magnetic field.

How emf is generated: By Faraday's law, the change in flux linkage **caused by the oscillating magnetic field** over time when the foil is under the induction heater (or positions 3-5), generates an induced emf.

Why are there eddy currents: Since the foil is **an extended piece of electrically conducting material**, the induced emf produces an eddy current that flows in the foil. [3]

The resistance of the foil and the eddy current cause the foil to heat up and melts the glue.

(iii) The amount of heat produced in the aluminium foil can be estimated using a small coil placed underneath the induction heater. The coil has a cross-sectional area of 2.40 cm^2 and contains 150 turns of wire. The resistance of the coil is $6.8 \times 10^{-3}\ \Omega$. Given that the magnetic flux density increased from zero to 500 mT in 0.30 s,

1. calculate the maximum magnetic flux linkage through the coil, and

$$\Phi = NBA = 150 \times 0.500 \times \frac{2.4}{100 \times 100}$$

$$\Phi = 1.8 \times 10^{-2}\ Wb$$

maximum magnetic flux linkage = ... Wb [2]

2. determine the power dissipated by the coil.

$$\varepsilon = \frac{1.8 \times 10^{-2}}{0.30} = 6.0 \times 10^{-2}\ \text{V}$$

$$P = \frac{\varepsilon^2}{R} = 0.529\ \text{W}$$

power dissipated = ... W [2]

(iv) Explain if this method can be used to fix a plastic seal around the bottle instead.

No. Plastic is an electrical insulator in which eddy current cannot flow.

Allow: non electrical conductor.

..... [1]

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6 **(a)** Describe three observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

Any three of the below:
1) There is a minimum frequency of radiation required, below which photoelectric emission does not occur.
2) There is no time lag between the illumination of the metal surface and the emission of photoelectrons, if the frequency of radiation is higher than the threshold frequency.
3) The maximum kinetic energy of the photoelectron is dependent on the frequency of light but independent of the intensity of radiation.
4) The rate of emission of photoelectrons is proportional to the intensity of radiation.

[3]

(b) Light of wavelength λ is incident on a metal surface having a work function energy Φ. Photoelectrons of maximum kinetic energy E_{MAX} are emitted from the surface.

The variation with $1/\lambda$ of E_{MAX} is shown in Fig. 6.1.

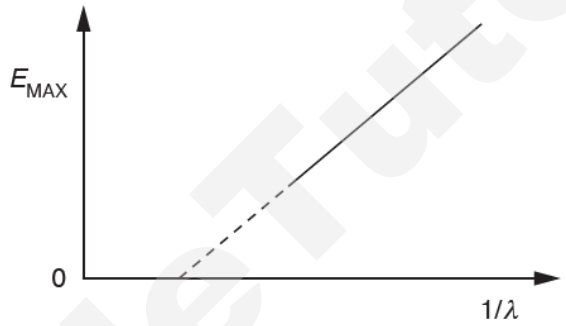

Fig. 6.1

(i) Explain why the gradient of the line in Fig. 6.1 does not depend on the type of the metal surface.

$$\frac{hc}{\lambda} = \Phi + E_{MAX}$$

$$E_{MAX} = hc\left(\frac{1}{\lambda}\right) - \Phi$$

The gradient of the graph is given by hc, where h is the Planck constant and c is the speed of light in free space. Since both h and c are constants, the gradient does not depend on the type of the metal surface.

[2]

(ii) The work function energy of sodium is 2.28 eV. Determine the minimum wavelength λ_o at which E_{MAX} is zero.

$$\frac{hc}{\lambda_o} = \Phi + 0$$

$$\frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda_o} = 2.28(1.60\times10^{-19})$$

$$\lambda_o = 5.45\times10^{-7}\ \text{m}$$

minimum wavelength = ... m [2]

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(c) An electron gun is used to shoot a beam of electrons towards a screen, at a speed of 6.00×10^6 m s^{-1}, through a slit of width 2.00 mm. Determine the distance between the slit of the gun and the screen, in order to see the beam of electrons spread by 1.00 cm on the screen because of the uncertainty principle.

$\Delta x.\Delta p \geq h$

$\Delta x = 0.00200$ m

(i.e. uncertainty in position is due to slit width of gun from where electrons are ejected)

$$\Rightarrow \Delta p \geq \frac{6.63 \times 10^{-34}}{0.00200} = 3.32 \times 10^{-31} \text{ kg m s}^{-1}$$

Hence the minimum uncertainty in momentum of the particle is $\Delta p = 3.32 \times 10^{31}$ kg m s^{-1}.

$$p = mv = (9.11 \times 10^{-31})(6.0 \times 10^6) = 5.47 \times 10^{-24} \text{ kg m s}^{-1}$$

$$\tan\theta = \frac{\Delta p}{p} = \frac{3.32 \times 10^{-31}}{5.47 \times 10^{-24}} = 6.06 \times 10^{-8}$$

$$\therefore \frac{\Delta d}{d} = 6.06 \times 10^{-8} \text{ (where } \Delta d \text{ is the spreading of the electrons)}$$

$$d = \frac{0.0100}{6.06 \times 10^{-8}} = 1.65 \times 10^5 \text{ m}$$

distance = ... m [3]

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7 The walls of music halls are acoustically covered with a sound-absorbing panel that is able to absorb certain sound frequencies more than others.

One particular design is to use the resonance of a perforated panel as shown in Fig. 7.1.

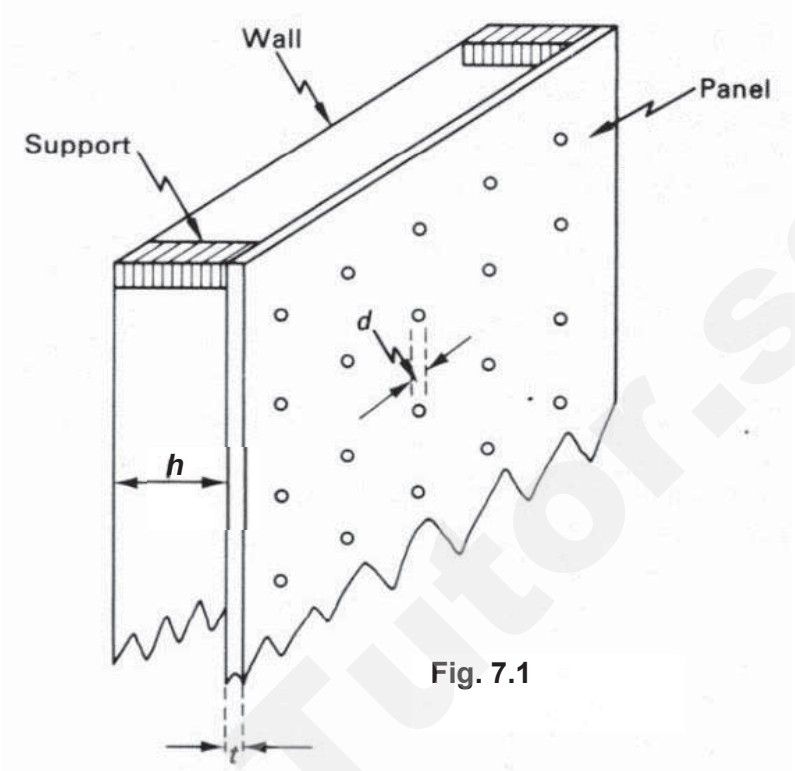

Fig. 7.1

It is found that this panel resonates at a particular frequency and hence can absorb sounds of that frequency more than others. A suggested formula for this resonant frequency f is given as:

$$f = k\sqrt{\frac{x}{h(t+0.8d)}} \qquad \text{--- Equation 7.1}$$

where $k = 5000$ mm s^{-1},
h = depth of airspace with unit mm,
t = thickness of panel with unit mm,
d = hole diameter with unit mm, and
x = percentage of panel surface area occupied by holes (e.g. $x = 10$ %)

Using identical hardboard panels having holes of the same diameter of 10 mm, the resonant frequencies f for different x values are measured, keeping h and t constant. The results are shown in Fig. 7.2:

x / %	2	4	6	8	10	12
f / Hz	530	750	920	1070	1190	1300

Fig. 7.2

(a) Using the results from Fig. 7.2, state and explain whether the formula for f given in Equation 7.1 is correct.

$$f = k\sqrt{\frac{x}{h(t+0.8d)}}$$

Assume f = A√x where A is constant

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When f = 530, x = 2% A = 375	When f = 750, x = 4% A = 375	When f = 920, x = 6% A = 376

Since A is almost constant, the formula of f is correct.

..... [3]

(b) Determine suitable values for h and t when x = 10 %, such that the results from Fig. 7.2 satisfy the given formula for f in Equation 7.1.

A = 375, $\Rightarrow \frac{k}{\sqrt{h(t+0.8d)}} = 375$

Assume t = 2mm , h = 18 mm

Acceptable range for t: 1 – 6 mm
Acceptable range for h = 18 – 12 mm

h = ... mm

t = ... mm [2]

(c) Using a panel with x fixed at 10 % and d fixed at 5 mm, the engineer decides to investigate the effect of filling the air space with 2 different absorbers. He obtains the absorption characteristics shown in Fig. 7.3.

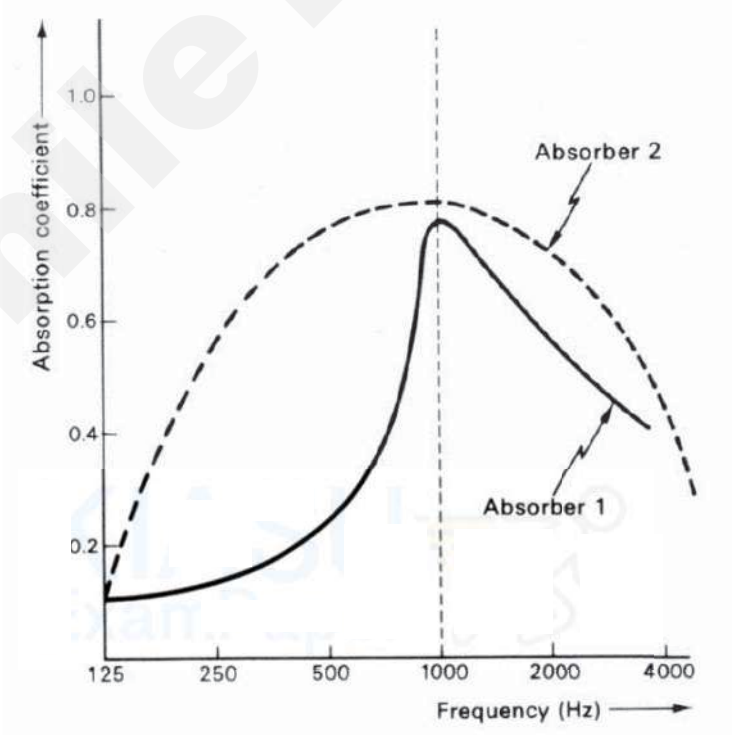

Fig. 7.3

Absorption coefficient is an indication of how much sound waves can be absorbed i.e. the higher the absorption coefficient, the stronger the absorption.

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(i) Using your knowledge on resonance, state one effect that absorbers have on the resonant frequency when they are inserted into the air space.

The resonant frequency will decrease

..... [1]

(ii) State and explain which of the two absorbers would be preferred in a room in which

1. absorption over a wide frequency range is required,

From the graph, the absorption coefficient for absorber 2 is higher than absorber 1 for all frequencies. Hence absorber 2 is preferred.

..... [1]

2. sounds below 500 Hz need amplification.

From the graph, the absorption coefficient for absorber 1 for frequency < 500 Hz is significantly lower than those values above 500 Hz. Hence absorber 1 is preferred. [1]

8 In 2012 skydiver Felix Baumgartner jumped out of a helium-filled balloon from a height of 39 km above sea level. His free fall of over 36 km lasted 4 minutes and 20 seconds. In this free fall, he became the first person whose speed exceeded the speed of sound 330 m s^{-1}, without the use of an aeroplane or rocket.

During the fall, Felix Baumgartner opened his parachute at about 1500 m above sea level, when his speed is 192 km hr^{-1}, and he landed safely 15 minutes later. All height and speeds were recorded by GPS.

Some data on the air atmosphere and helium is collected and given in Fig. 8.1.

	sea level	**39 km above sea level**
Temperature of atmosphere / °C	15	-25
Atmospheric pressure / Pa	101 000	318
Air density	-	0.00447
Helium density / kg m^{-3}	-	0.00065

Fig. 8.1

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(a) Using data given in Fig. 8.1, determine the minimum volume of helium required in the balloon at sea level, for a skydiver in the helium-filled balloon to reach a height of 39 km above sea level at constant speed. Assume that the total mass of the skydiver and the helium-filled balloon is 3140 kg, and that helium behaves as an ideal gas.

ΣF = 0 (since speed is constant)
Upthrust – weight of skydiver = 0
V(0.00447)g – 3140g = 0
V = 7.02 x 10^5 m^3

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{(101000)V_1}{15+273} = \frac{318(7.02x10^5)}{-25+273}$$

V_1 = 2600 m^3

(Solution if assume weight of helium unknown)
ΣF = 0
U – 3140g – weight of helium air in balloon = 0
V(0.00447)g – 3140g – V(0.00065)g = 0
V = 8.2 x 10^5 m^3

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{(101000)V_1}{15+273} = \frac{318(8.2x10^5)}{-25+273}$$

V_1 = 3000 m^3

..... m^3 [3]

Two main forces acting on the skydiver of mass *m* are his weight and air resistance. The air resistance *F* can be written as follows

$$F = \tfrac{1}{2} C_D A \rho v^2$$

where ρ is the density of air, *A* is effective cross-sectional area and C_D is the drag coefficient.

(b) **(i)** Show that the terminal speed v_T that can be achieved by the skydiver as he falls is given by

$$v_T = \sqrt{\frac{2mg}{C_D A \rho}}$$

At terminal speed, net force = 0

F – mg = 0
$mg = \tfrac{1}{2} C_D A \rho v_T^2$

[1]

(ii) Explain why the skydiver's terminal speed will not be constant as he falls.

The air density will increase as he falls. .....

..... [1]

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(c) The acceleration a of the sky diver when he is falling at a speed v is given by

$$a = g\left(\frac{v^2}{v_T{}^2} - 1\right) \qquad \text{--- Equation 8.1}$$

The variation of the skydiver's speed with time as he falls is shown in Fig 8.2. The terminal speed v_T based on the expression given in **(b)(i)** is also plotted in Fig. 8.2 (denoted by the dashed line).

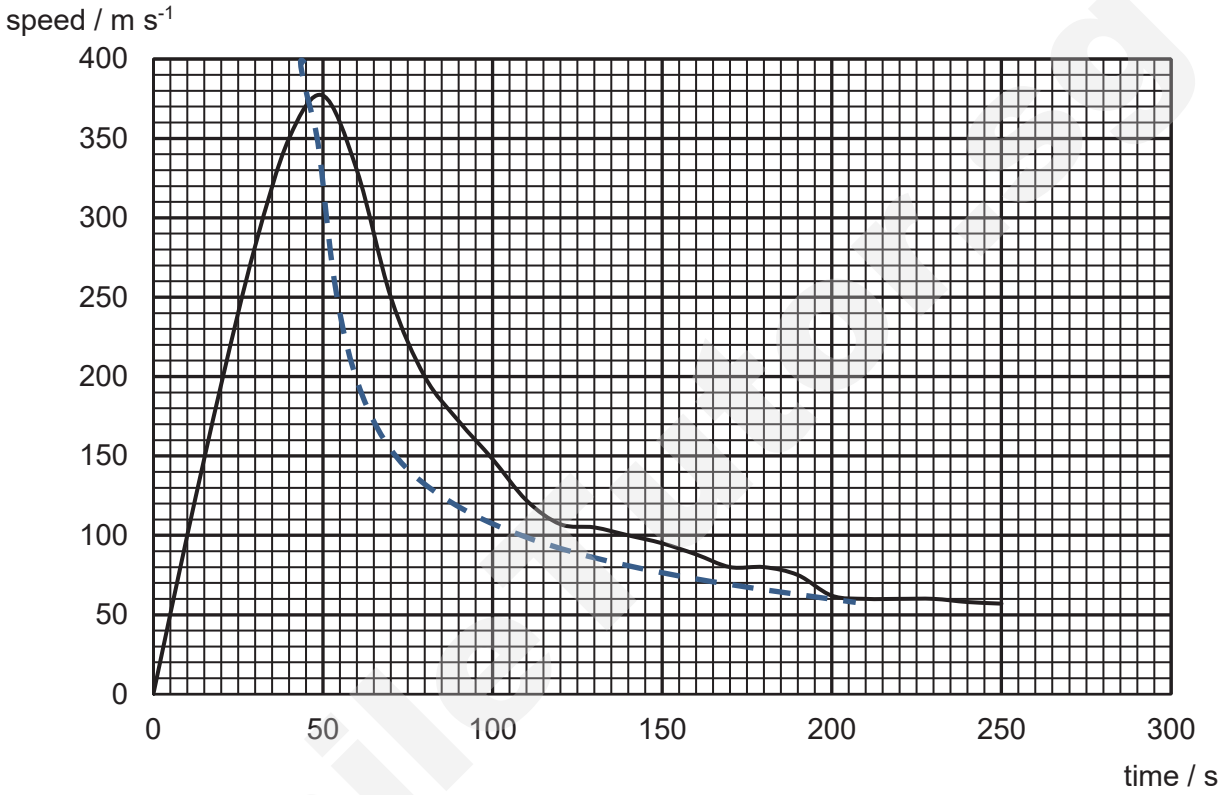

Fig. 8.2

(i) Deduce from Fig 8.2 the duration of time when the skydiver exceeds the speed of sound during his fall.

Duration is about 22 – 24 s.

duration = ... s [1]

(ii) Use Fig 8.2 to determine the total distance fallen when the sky diver reaches his maximum speed.

Total distance = area under the graph

Acceptable range = 10500 – 12500 m

total distance fallen = ... m [2]

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(iii) Using Fig. 8.2 and Equation 8.1, describe and explain the variation in the speed of the skydiver from time = 50 s to 250 s.

The speed of the skydiver is decreasing from 50 s – 200 s. Since his speed is greater than terminal speed, based on Equation 8.1, the acceleration is negative causing his speed to decrease until V =V_T . He reached an almost constant speed from 200 – 250 s.

[2]

(d) **(i)** Suggest why a helium-filled balloon is used to bring the skydiver to a height of 39 km above sea level, instead of using an aircraft.

The density of the air is too small to generate enough lift force at this height.

[1]

(ii) Suggest a major health hazard to the skydiver at such a high attitude, even with the use of oxygen supply.

1) Due to the extreme low pressure, his blood will boil.
OR
2) Exposure to comics rays/dangerous radiation causing cancers.
3) Unknown virus from space.

[1]

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H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

CLASS

TUTOR'S NAME

PHYSICS 9749/03

Paper 3 Longer Structured Questions **21 September 2017**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

You are advised to spend about one and a half hours on Section A, and about thirty minutes on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Total	

This document consists of **22** printed pages.

[Turn over

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Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

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Section A

Answer **all** the questions in the spaces provided.

1 A hot air balloon P is moving vertically upward at a uniform speed when weather condition turns windy. A constant breeze blows horizontally across the sky at a speed 4.0 m s^{-1}, which causes the hot air balloon to travel with a resultant velocity 11 m s^{-1} at an angle θ to the horizontal, as shown in Fig. 1.1 below.

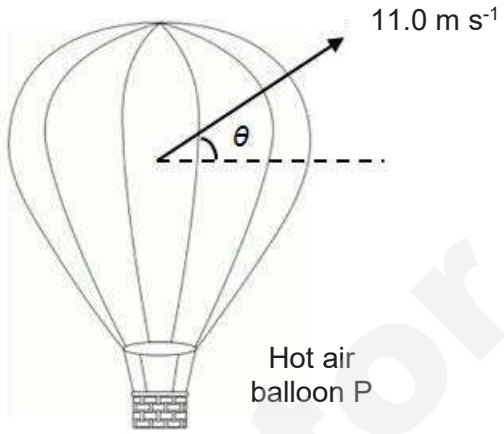

Fig. 1.1

A sandbag is released from the balloon P. Ignore the effects of air resistance. Assuming that the sandbag has yet to land on the ground after 2.3 s, and that the velocity of balloon P is not affected by the release of the sandbag,

(a) determine the horizontal distance of the sandbag from balloon P after 2.3 s, and

Since the sandbag and hot air balloon have the same horizontal speed, the horizontal distance between them will be 0 m at all time before the landing of the sandbag.

horizontal distance = ... m [1]

(b) show that the vertical distance of the sandbag from balloon P after 2.3 s is 26 m. [2]

The vertical speed of the balloon is $\sqrt{11.0^2 - 4.0^2} = 10\ ms^{-1}$

$S_y = u_y t + ½ a_y t^2$

For the sandbag, $S_y = u_y t + ½ a_y t^2$
$= (+10)(2.3) + ½ (-9.81)(2.3)^2$
$= - 2.9$ m
(2.9 m below the initial point of release)
For the hot air balloon, $s = (10)(2.3) = 23$ m
(23 m above the initial point of release)
The distance between them is $23 + 2.9 \approx 26$ m

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(c) There is a second hot air balloon Q which is at a stationary position below the first hot air balloon P. At the instant when the released sandbag passes in front of this second air hot balloon Q at 2.3 s, the person inside balloon Q throws another sandbag at this first sandbag that was released from P. The second sandbag is thrown from Q at an angle of 45° below the horizontal.

(i) Determine the speed at which the second sandbag is thrown from Q if both sandbags reach the ground at the same time.

For them to reach the ground at the same time, they have to have the same vertical speed at the same displacement,
For the first sandbag, the vertical speed at that time is $v_y = u_y + at$
$= (10)+(-9.81)(2.3)$
$= -12.6$
For the second sandbag, the speed, $v \sin 45 = 12.6$
$v = 18\ ms^{-1}$ (17.8)

speed = ... m s^{-1} [2]

(ii) The person inside Q wants the sandbag that was thrown out from Q in **(i)** to reach the ground within a shorter time. Therefore he throws out another sandbag from Q with the same speed and angle of projection as the sandbag which he threw out in **(i)** but this time, he uses a heavier sandbag. Comment on whether he will succeed.

He will not succeed as acceleration due to gravity is independent of mass.

..... [1]

2 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 2.1.

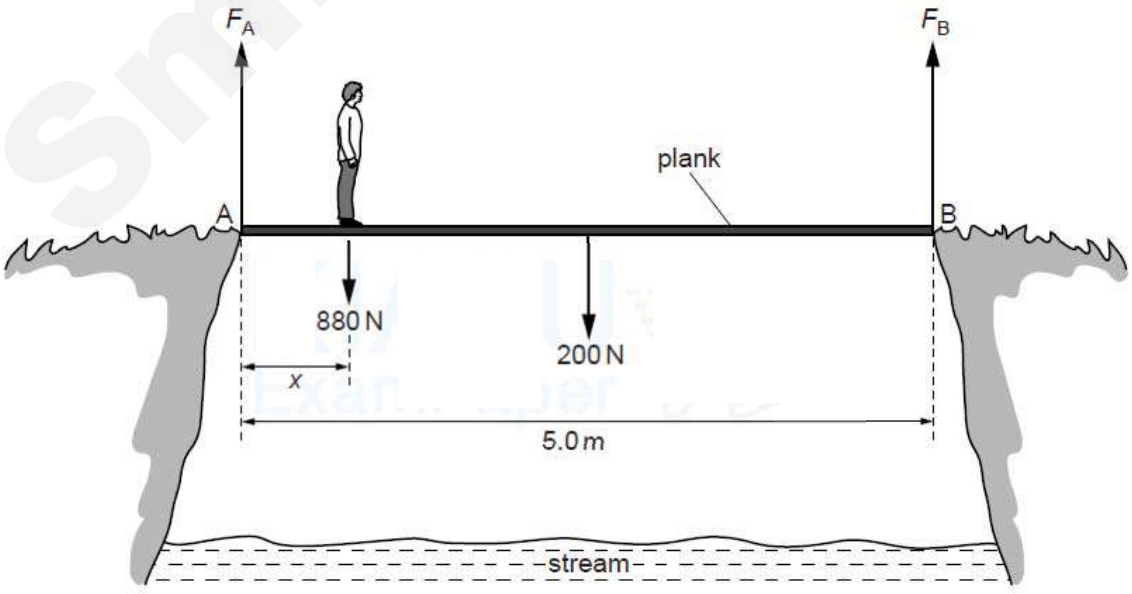

Fig. 2.1

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A man of weight 880 N stands at a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B. As the man moves along the plank, the plank is always in equilibrium.

(a) **(i)** Define *moment of a force*.

The moment of a force about a point is defined as the product of the force and the perpendicular distance from the line of action of the force to that point.

..... [1]

(ii) Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

Since the plank is in equilibrium, the resultant force is zero. As there are no horizontal forces, the vertical forces must balance.
The sum of force exerted by man on plank (equal to weight of man) and weight of plank must be equal to sum of F_A and F_B , and as the mass of man and plank do not change, the sum of F_A and F_B are constant.

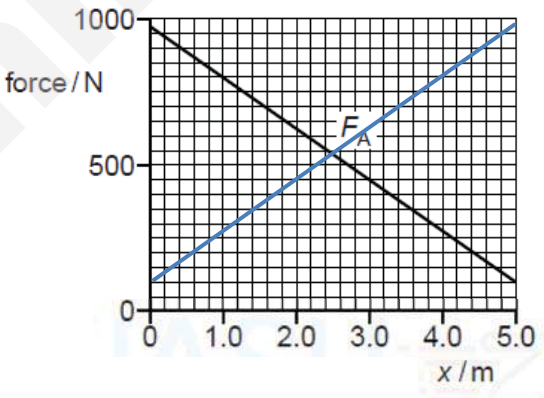
..... [2]

(iii) The man stands at a distance x = 0.50 m from end A. Determine the magnitude of F_B.

(anticlockwise moments) = (clockwise moments)
$F_B \times 5.0 = 880 \times 0.5 + 200 \times 2.5$
$F_B = (440 + 500) / 5.0 = 188$ N

F_B = ... N [2]

(b) The variation with distance x of the magnitude of force F_A is shown in Fig. 2.2.



On Fig. 2.2, sketch ion with x of the magnitude of force F_B. [2]

A straight line with positive gradient with start point (0.0, 100) and finish point (5.0 , 980)

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3 A student attempts to set up a "Rube Goldberg Machine", which is a contraption consisting of a series of devices that perform simple tasks which are linked together to produce a domino effect, where the activation of one device triggers the next device in the sequence.

A part of the contraption is shown in Fig 3.1. It consists of a small block of mass 40 g, initially at rest, which slides down a rough slope from X to P. When the block reaches point P, it attains a speed of 0.35 m s^{-1}.

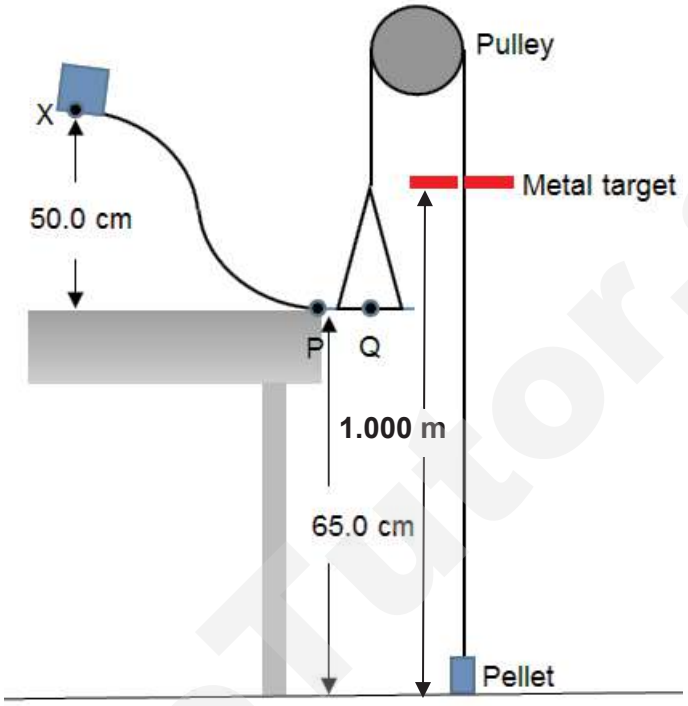

Fig. 3.1

(a) Determine the work done against friction when the block slides from X to P.

Loss in GPE = Gain in KE + Work done against friction
$(0.040 \times 9.81 \times 0.500) = (0.5 \times 0.040 \times 0.35^2)$ + Work done against friction
Work done against friction = 0.194 J (2 s.f. or 3 s.f. allowed)

work done = ... J [2]

(b) At P, the block continues to slide forward a little and comes to a complete stop at point Q on a movable platform connected to a pulley. Its weight causes the pulley to turn and the block eventually hits the ground 65.0 cm below, lifting a small 15 g rectangular pellet from the ground in the process.

(i) Determine the speed of the pellet just as the 40 g block hits the ground.

Loss in GPE = Gain in KE
$[(0.040-0.015) \times 9.81 \times 0.650] = [0.5 \times (0.040+0.015) \times v^2)$
$v = 2.41$ m s^{-1}

speed = ... m s^{-1} [2]

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(ii) The contraption is designed such that when the pellet hits a metal target during its upward motion, it will make a loud sound. The target is placed 1.000 m above the ground. State and explain whether the pellet will hit the target, showing your working clearly.

$v^2 = u^2 + 2as$
$0^2 = 2.41^2 + 2(-9.81)\ s$
$s = 0.296$ m
Maximum height reached by pellet = 0.296 + 0.650 = 0.946 m
Hence the pellet will not hit the target.

OR

Gain in GPE = Loss in KE
$0.015 \times 9.81 \times h = (0.5 \times 0.015 \times 2.41^2)$
$h = 0.296$ m
Maximum height reached by pellet = 0.296 + 0.650 = 0.946 m
Hence the pellet will not hit the target.

..... [3]

(iii) State an assumption you have made in your calculation in **(ii)**.

Any of the following:

Air resistance is negligible.

The string has negligible mass.

..... [1]

4 A turntable is rotating at a constant speed of 15 revolutions per minute. A small five-cent coin of mass 1.56 g is placed at the rim of the turntable and it moves with the turntable without slipping.

(a) Show the angular velocity of the rotating coin is 1.57 rad s^{-1}. [1]

$\omega = 2\pi f$
$= 2 \times \pi \times \frac{15}{60}$
$= 1.57$ rad s^{-1}

(b) Given that the kinetic energy of the coin is 2.5×10^{-5} J, determine the radius of the turntable.

$\frac{1}{2}mv^2 = 0.000025$
$\frac{1}{2}(0.00156)v^2 = 0.000025$
$v = 0.179$ m s^{-1}

$v = r\omega$
$r = \frac{v}{\omega} = \frac{0.179}{1.57}$

$r = 0.114\ m$

radius = ... m [2]

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(c) If the maximum friction between the coin and the turntable is 0.012 N, calculate the maximum number of complete revolutions that the turntable can make per minute, such that the coin can still remain on the turntable.

Friction provides the centripetal force for the coin to remain in circular motion:

$f = mr\omega^2$
$0.012 = 0.00156 \times 0.114 \times \omega^2$
$\omega_{max} = 8.21$ rad s^{-1}

$\omega = 2\pi f$
$f_{max} = \frac{\omega}{2\pi} = 1.31$ Hz

max. number of revolutions per minute = 1.31 × 60 = 78 (round down)

maximum number of revolutions per minute = ... min^{-1} [3]

(d) If the rotational speed of the turntable continues to increase, the coin is observed to slip off the turntable and fall to the ground. Describe the path of the coin after it leaves the turntable until it reaches the ground.

Coin initially moves off at a tangent to the circular path at the point of departure. It then falls to the ground in a parabolic path like a typical projectile motion. [2]

5 **(a)** In order to determine the internal resistance of a 12.00 V battery, a student sets up the circuit shown in Fig. 5.1. The rheostat CD has a maximum resistance of 1000 Ω.

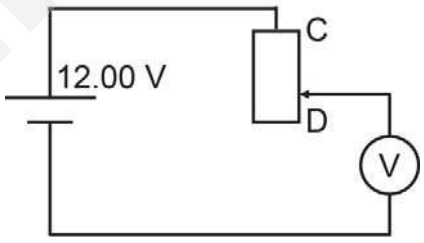

Fig. 5.1

When the sliding contact of the rheostat is placed at C, the voltmeter reading is 11.99 V. When the sliding contact moves from C to D, the voltmeter reading drops from 11.99 V to 11.00 V.

(i) State the potential difference across the internal resistance of the battery when the sliding contact of the rheostat is placed at C.

potential difference = 0.01 V [1]

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(ii) Explain why the presence of internal resistance in the battery reduces its output power.

Internal resistance reduces the terminal potential difference of the battery.

Since the output power is proportional to its terminal p.d., the presence of internal resistance reduces the output power of the battery. [1]

(iii) Determine the internal resistance *r* of the battery and internal resistance *R* of the voltmeter.

Using potential divider concept,

$$\left(\frac{r}{r+R}\right)\varepsilon = V_r$$
$$r\varepsilon = rV_r + RV_r$$
$$r(\varepsilon - V_r) = RV_r$$
$$r = \frac{V_r}{\varepsilon - V_r}R \quad -(1)$$
$$\left(\frac{R}{r+1000+R}\right)\varepsilon = V_R$$
$$R\varepsilon = rV_R + RV_R + 1000V_R$$
$$rV_R = R(\varepsilon - V_R) - 1000V_R$$
$$r = \frac{\varepsilon - V_R}{V_R}R - 1000 \quad -(2)$$

Substitute (1) into (2),

$$\frac{V_r}{\varepsilon - V_r}R = \frac{\varepsilon - V_R}{V_R}R - 1000$$
$$\frac{0.01}{12.00 - 0.01}R = \frac{12.00 - 11.00}{11.00}R - 1000$$
$$R = 11100\ \Omega$$

Substitute $R = 11100\ \Omega$ into (1),

$$r = \frac{V_r}{\varepsilon - V_r}11100$$
$$r = 9.26\ \Omega$$

r = 9.26 Ω

R = 11 100 Ω [4]

(b) In another circuit shown in Fig. 5.2, a uniform wire AB of length 80.0 cm and resistance 1.5. Ω is connected in series with a resistor of 5.0 Ω and a cell of e.m.f. 9.0 V with internal resistance 1.0 Ω.

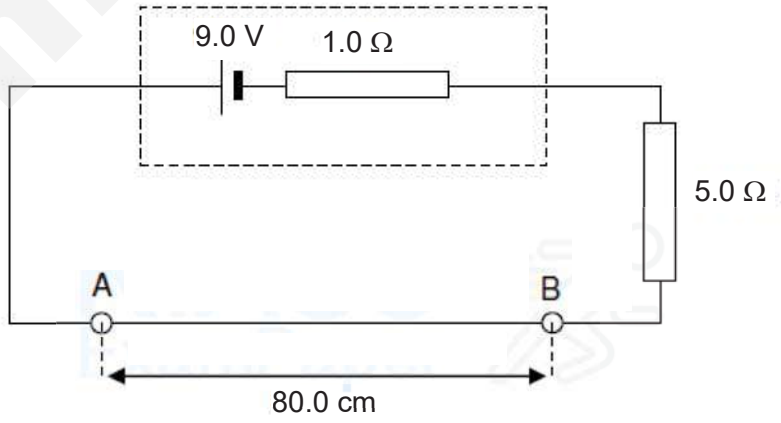

Fig. 5.2

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(i) Calculate the potential difference across wire AB.

Using potential divider rule,

$$\left(\frac{1.5}{1.0+5.0+1.5}\right)9.0 = V_{AB}$$

$$V_{AB} = 1.8\ \text{V}$$

potential difference = 1.8 V [2]

(ii) A cell C of e.m.f. 1.5 V and internal resistance 0.80 Ω is connected to the circuit in Fig. 5.2, as shown in Fig. 5.3. The movable contact D can be connected to any point along wire AB.

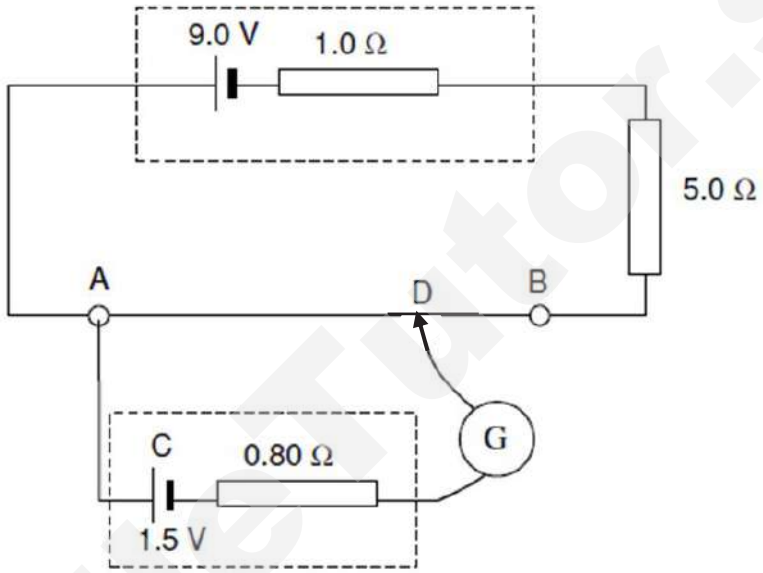

Fig. 5.3

Calculate the length of AD when there is zero current in the galvanometer.

0 A in galvanometer: $V_{AD} = 1.5\ \text{V}$

Using potential divider rule,

$$\frac{1.5}{1.8} = \frac{L_{AD}}{0.800}$$

$$L_{AD} = 0.67\ \text{m}$$

length = 0.67 m [2]

6 **(a)** State in words the *first law of thermodynamics*.

In a closed system, the increase in internal energy is equal to the sum of the heat supplied to the system and the work done on the system. [1]

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(b) An adiabatic process is one in which no heat is supplied to or extracted from a system.

(i) Determine the change in the internal energy of an ideal gas when the gas does 600 J of work in an adiabatic process.

$\Delta U = Q_{in} + W_{on}$
$= 0 - 600$
$= -600$ J

change in internal energy = ... J [1]

(ii) Hence describe how the temperature of the gas in **(i)** will change at the end of the adiabatic process.

The temperature of the gas will decrease because the internal energy of an ideal gas is proportional to the temperature of the gas. [1]

(c) A heat pump is a device which works by changing the state of a gas through a cycle of operations such those shown in Fig. 6.1, changing the state of a sample of gas from A to B, then to C, and then to D, and eventually back to A.

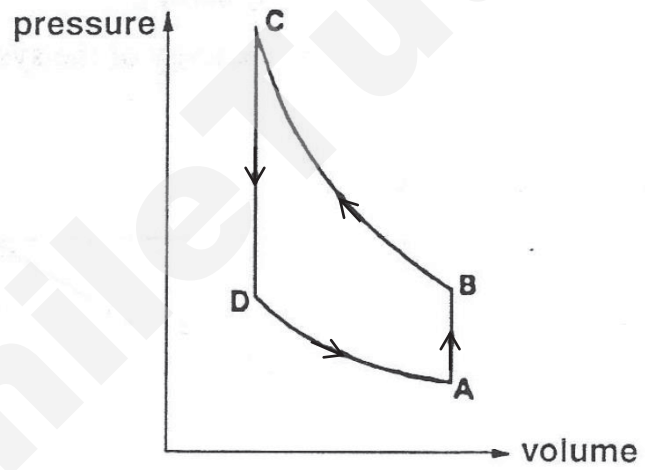

Fig. 6.1

Between A and B the gas absorbs heat from the atmosphere, and between C and D it delivers heat to the inside of a building. Processes BC and DA are adiabatic.

For a certain heat pump, the heat supplied to the gas during each part of the cycle and the corresponding work done on the gas are given in Fig. 6.2. The cycle is completed 20 times per second.

Section of cycle	Heat supplied to gas / J	Work done on gas / J
A → B	280	0
B → C	0	190
C → D	-400	0
D → A	0	-70

Fig. 6.2

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(i) Fill in the blank spaces in Fig. 6.2. [2]

(ii) Explain why the total change in the internal energy of the gas in the pump during a complete cycle must be zero.

A cyclic process brings the state of a system through a sequence of changes and finally returns back to its original state, that is, to its original internal energy. Thus the change in internal energy at the end of a complete cycle is zero. [1]

OR

A cyclic process brings the state of a system through a sequence of changes and finally returns back to its original state, i.e. the original temperature. As internal energy is proportional to temperature, the internal energy at the end of the cycle is the same as all that at the beginning of the cycle

(iii) Calculate the minimum average power of the motor required to run the pump.

The motor of a heat pump does work on the gas.
Net work done per cycle = 190 – 70 = 120 J
Minimum average power = $\frac{120}{1/20}$ = 2400 W

minimum average power = ... W[2]

(iv) Calculate the average rate of supply of heat by the pump.

The heat supplied by the pump in one cycle = 400 J

Rate of heat supply = $\frac{400}{1/20}$ = 8000 W

average rate of supply of heat = ... W[2]

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7 **(a)** Red and green light, of wavelengths 640 nm and 520 nm respectively, are simultaneously directed through a narrow slit onto a diffraction grating. The grating is at right angles to the light and has a line spacing of 1.60 μm.

(i) Complete Fig. 7.1 by calculating the values of all the angles of diffraction corresponding to different orders of maxima for both colours. [3]

order *n*	angle for red maximum / °	angle for green maximum / °
0	0	0
1	23.6	19.0
2	53.1	40.5
3		77.2

Fig. 7.1

(ii) Sketch on Fig 7.2 the approximate pattern that would be seen on a screen behind the diffraction grating. Label the red and green maxima **R** and **G** respectively. [2]



Fig. 7.2

(iii) Suggest and explain how the spacing of the maxima drawn on Fig. 7.2 can be used to determine whether the light is directed normal to the grating.

The spacing of the bright lines for each order and colour from the central maximum should be symmetrical if the light is directed normal to the grating. The path difference between each wavetrain entering the slits will be zero if the light is directed normal to grating.

[2]

(iv) Explain why the same pattern will not be observed on the screen if the diffraction grating has irregularly spaced slits.

If the slits are irregularly slits, then the path difference between each wave exiting each slit will be different. Hence it is very difficult to have constructive interference taking place at most position.

[1]

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(b) **(i)** The grating in **(a)** is replaced with a double-slit setup that has the same spacing between slits as the grating in **(a)**. Describe how the new pattern produced will differ from the one drawn in **(a)(ii)**.

1st Difference : Instead of discrete colour lines with different spacing, a dark and bright fringe pattern of equal spacing will be observed .

2nd Difference: Instead of distinct red and green colours lines, the bright red fringes will be slightly longer than green fringes and mostly overlapped . [2]

(ii) The grating in **(a)** is replaced with a single slit whose slit width has the same value as the slit spacing of the grating in **(a)**. This produces another pattern. Determine the angle θ between two lines, drawn from the centre of the slit to the central maximum and to the first order red minimum in the pattern respectively.

$$\sin\theta = \frac{\lambda}{b} = \frac{6.4x10^{-7}}{1.6x10^{-6}}$$

θ = 0.41 rad

θ = ... rad [1]

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Section B

Answer **one** question from this Section in the spaces provided.

8 **(a)** **(i)** Define *electric field strength*.

The electric field strength at a point in an electric field is defined as the force per unit **positive** charge acting on a test charge placed at that point.

[1]

(ii) With reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

The electric field lines, along which the electric forces exerted by the charged sphere on other charges act, are always perpendicular to the surface of the sphere (i.e. the electric field lines are radial).

Hence the field lines appear to originate from the centre of the sphere, so the charge on the sphere may be considered to act as a point charge at its centre. [2]

(b) Electrons 'leak' easily from the surface of many stars, so these stars acquire a positive charge. The charging stops when the charge on the star is so large that protons at the surface of the star also begin to be repelled.

This occurs when the sum of the gravitational potential energy and the electric potential energy of a proton at the surface of the star is zero. The star is then considered to be in steady state. It is assumed that each star takes on the shape of a sphere.

(i) Write down an equation that relates the gravitational potential energy and the electric potential energy of a proton at the surface of a star that has just stopped charging, **defining clearly** all the symbols used in the equation.

$-\frac{GMm}{r}+\frac{Qq}{4\pi\varepsilon_o r}=0$, where

G = gravitational constant,
M = mass of star,
m = mass of proton,
r = radius of star,
Q = maximum charge of star,
q = charge of proton,
ε_o = permittivity of free space.

[2]

(ii) Show that, in the steady state, the maximum charge carried by a star of a given mass is independent of its radius. [1]

$$-\frac{GMm}{r}+\frac{Qq}{4\pi\varepsilon_o r}=0$$

$$\Rightarrow Q=\frac{4\pi\varepsilon_o GMm}{q}$$

Hence the maximum charge Q of the star is independent of its radius r.

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(iii) Calculate the maximum charge for Sun, which has a mass of 2.0×10^{30} kg.

$$Q = \frac{4\pi\varepsilon_o GMm}{q}$$
$$= \frac{4\pi(8.85\times10^{-12})(6.67\times10^{-11})(2.0\times10^{30})(1.67\times10^{-27})}{1.60\times10^{-19}} = 155 \text{ C}$$

maximum charge = ... C [1]

(c) Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart. Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 8.1.

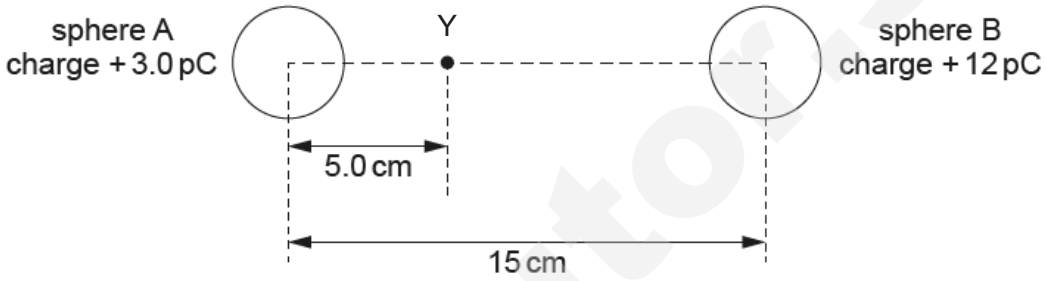

Fig. 8.1

Point Y lies on the line joining the centres of the spheres and is at a distance of 5.0 cm from the centre of sphere A.

(i) Explain why the electric field strength in both spheres is zero.

In the presence of an electric field, the charges in a conductor would move. Since the charges in spheres A and B do not move, this means that there is no resultant force exerted on these charges. Hence there is no electric field, so the electric field strength in both spheres is zero.

..... [1]

(ii) Show that the electric field strength is zero at point Y. Explain your working. [3]

At point Y, the electric field strength due to sphere A is directed towards the right, while that due to sphere B is directed towards the left.

Hence resultant electric field strength at Y
$$= E_A - E_B$$
$$= \frac{Q_A}{4\pi\varepsilon_o r^2} - \frac{Q_B}{4\pi\varepsilon_o (0.15-r)^2}$$
$$= \frac{3.0\times10^{-12}}{4\pi(8.85\times10^{-12})(0.050)^2} - \frac{12\times10^{-12}}{4\pi(8.85\times10^{-12})(0.15-0.050)^2}$$
$$= 0$$

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(iii) Explain how the electric field strength at point Y is related to the electric potential at that point.

The electric field strength at point Y is equal to the **negative** of the **electric potential gradient** at that point.

OR
The magnitude of the electric field strength at point Y is equal to the value of the electric potential gradient at that point, and the direction of the electric strength is in the direction of decreasing electric potential.

[1]

(iv) Calculate the electric potential at point Y.

$$V = V_A + V_B$$
$$= \frac{3.0\times10^{-12}}{4\pi\varepsilon_o(0.050)} + \frac{12\times10^{-12}}{4\pi\varepsilon_o(0.10)}$$
$$= 1.62 \text{ V}$$

electric potential = ... V [2]

(v) A silver-107 nucleus ($^{107}_{47}Ag$) has speed v when it is a long distance from point Y. Use your answer in **(iv)** to calculate the minimum value of v such that the nucleus can reach point Y.

Loss in KE = Gain in EPE

$$\frac{1}{2}mv^2 = qV$$
$$\frac{1}{2}(107u)v^2 = 47eV$$
$$\frac{1}{2}(107)(1.66\times10^{-27})v^2 = 47(1.60\times10^{-19})(1.62)$$
$$v = 1.17\times10^4 \text{ m s}^{-1}$$

v = ... m s^{-1} [2]

(d) Sphere B in Fig. 8.1 is removed and placed at the centre of two parallel, large metal plates which are connected to the terminals of a battery with e.m.f. 10 V, as shown in Fig. 8.2. The distance between the plates is 2.0 mm.

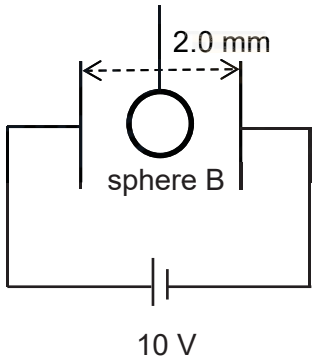

Fig. 8.2

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(i) Calculate the electric force F_1 exerted by the plates on sphere B.

$$F_1 = Q_B\left(\frac{\Delta V}{d}\right)$$
$$= \left(12\times10^{-12}\right)\left(\frac{10}{0.0020}\right) = 6.0\times10^{-8}\ \text{N}$$

F_1 = ... N [2]

(ii) Another conducting sphere C, which is initially uncharged and has a radius twice that of sphere B, is placed in contact with sphere B. Determine the new charge on sphere B after sphere C has been removed.

$$V_B = V_C$$
$$\frac{Q_B}{4\pi\varepsilon_o r} = \frac{Q_C}{4\pi\varepsilon_o (2r)}$$
$$Q_C = 2Q_B$$

Since $Q_B + Q_C = 12\times10^{-12}$,
$$\Rightarrow 3Q_B = 12\times10^{-12}$$
$$Q_B = 4.0\times10^{-12}\ \text{C}$$

new charge = ... C [2]

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9 In 1954 the world's first nuclear-powered submarine, the USS Nautilus, was launched. Before that, submarines used diesel-electric power. Enriched uranium, which consists of a high percentage of uranium-235 isotope ($^{235}_{92}U$), was used as the source of fuel for USS Nautilus.

Naturally occurring uranium consists mainly of uranium-238 isotope ($^{238}_{92}U$) and only 0.72% of it is made up of $^{235}_{92}U$. It can be enriched to increase the percentage of $^{235}_{92}U$ by up to 90% so as to allow nuclear fission reaction to take place effectively.

(a) In the nuclear reactor of the submarine, the process of nuclear fission is caused by the bombardment of $^{235}_{92}U$ with a slow-moving neutron as described by the following equation:

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

(i) Explain what is meant by the nuclear binding energy of a uranium-235 nucleus.

The binding energy of a uranium-235 nucleus is defined as the energy needed to separate completely the nucleus into its individual nucleons.

[1]

(ii) Sketch the variation of average binding energy per nucleon with nucleon number on Fig 9.1. In your sketch, mark the relative positions of $^{235}_{92}U$, barium-144 ($^{144}_{56}Ba$) and krypton-89 ($^{89}_{36}Kr$). [2]

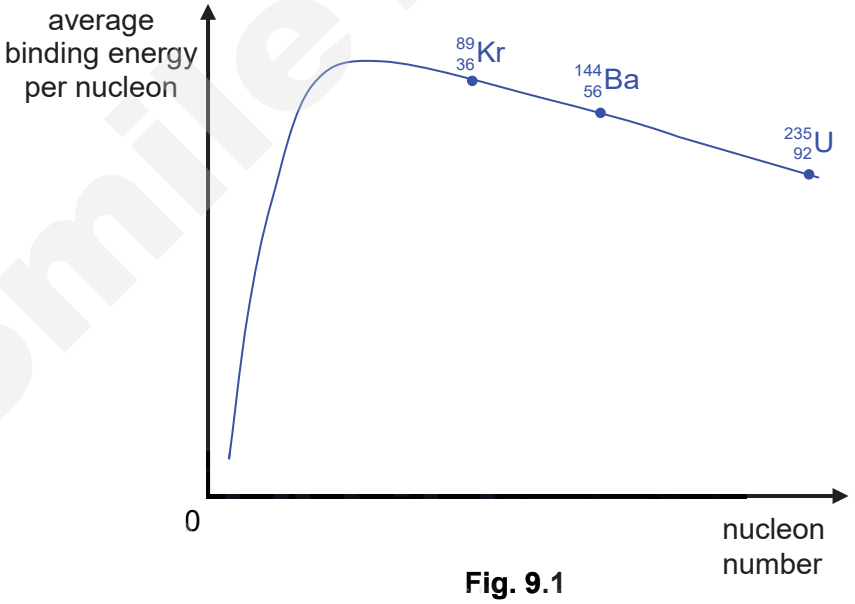

Fig. 9.1

(iii) Using the concept of binding energy, explain why the fission of $^{235}_{92}U$ into $^{144}_{56}Ba$ and $^{89}_{36}Kr$ results in a release of energy.

The sum of the binding energies of the products of the fission reaction, $^{144}_{56}Ba$ and $^{89}_{36}Kr$ is higher as compared to the binging energy of the reactant, $^{235}_{92}U$. As such, less energy is needed to separate $^{235}_{92}U$ and more energy is consequently released when the products $^{144}_{56}Ba$ and $^{89}_{36}Kr$ are formed, resulting in a net release of energy.

[2]

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(iv) The masses of some of the particles and nuclei involved in the reaction are given in Fig. 9.2.

	mass
$^{235}_{92}U$	235.044 *u*
$^{144}_{56}Ba$	143.923 *u*
$^{89}_{36}Kr$	88.917 *u*
$^{1}_{0}n$	1.009 *u*

Fig. 9.2

Calculate the energy released for one such fission reaction, to three significant figures.

Energy released in a single fission
$= \Delta mc^2$
$= [235.044 + 1.009 - (143.923 + 88.917 + 3 \times 1.009)] \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
$= 2.779 \times 10^{-11}$ J
$= 2.779 \times 10^{-11} / 1.60 \times 10^{-19} \times 10^6$
$= 174$ MeV

energy released = ... MeV [3]

(v) When tested under laboratory conditions, the total kinetic energy of the products in the fission reaction was found to be 168 MeV. Suggest a reason for the difference (if any) between this value and your answer in **(iv)**.

Other sources of energy such as gamma radiation may also be released in the fission reaction.

..... [1]

(vi) The nuclear reactor used to power the USS Nautilus has a power output of 10 MW. The submarine is designed to carry enough nuclear fuel to power the submarine for 25 years.

Assuming the actual energy released per fission reaction is 168 MeV, calculate the mass of $^{235}_{92}U$ that needs to be carried by USS Nautilus to achieve this.

Amount of energy needed
$= P\,t$
$= 10 \times 10^6 \times 25(365)(24)(3600)$
$= 7.884 \times 10^{15}$ J
Since one fission reaction can release 168 MeV of energy.
Therefore, number of $^{235}_{92}U$ required
$= 7.884 \times 10^{15} / (168 \times 10^6 / 1.60 \times 10^{-19}) = 2.933 \times 10^{26}$
Mass of required
$= 2.933 \times 10^{26} \times 235.044 \times 1.66 \times 10^{-27} = 114$ kg

mass of $^{235}_{92}U$ = ... kg [3]

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(vii) The fission reaction involving $^{235}_{92}U$ is effective as it is a type of nuclear chain reaction. Suggest why the reaction is considered a *chain reaction*.

The fission reaction produced three neutrons which have high energy. This will in turn react with more uranium-235 nucleus to trigger more fission reactions. [1]

(viii) State one advantage and one disadvantage in the use of nuclear power instead of diesel-electric power in providing energy for the submarine.

Advantage:

Any positive reasons relating to the small amount of fuel needed or to the sustainability of the fuel (less need of refuelling) will be accepted. [1]

Disadvantage:

Any reasons relating to the hazardous nature of the fission reactants and products (such as their radioactive nature, need of shielding or danger of meltdown) will be accepted. [1]

(b) In a sample of naturally occurring uranium, the isotope $^{238}_{92}U$, which has a half-life of 4.47×10^9 years, undergoes radioactive decay to form $^{206}_{82}Pb$.

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + \text{other decay products}$$

(i) Define *half-life*.

Half-life refers to the time needed for half the radioactive nuclei to decay. [1]

(ii) Besides $^{206}_{82}Pb$, the other decay products formed consist of alpha and beta particles. Determine the number of alpha and beta particles formed when one $^{238}_{92}U$ isotope decays to form $^{206}_{82}Pb$.

$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8\,^{4}_{2}He + 6\,^{0}_{-1}e$ (8 alpha particles and 6 beta particles)

number of alpha particles = ...

number of beta particles = ... [2]

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(iii) A sample of naturally occurring uranium contains 120 kg of $^{238}_{92}\text{U}$ after some of the isotopes have decayed to $^{206}_{82}\text{Pb}$. Given that the original mass of $^{238}_{92}\text{U}$ in the sample was 200 kg, determine the age of the sample.

$$m = m_0 e^{-\lambda t} \Rightarrow \lambda t = -\ln\left(\frac{m}{m_0}\right)$$

$$t = -\ln\left(\frac{m}{m_0}\right) \div \lambda = -\ln\left(\frac{m}{m_0}\right) \div \left(\frac{\ln 2}{t_{1/2}}\right) = -\ln\left(\frac{120}{200}\right) \div \left(\frac{\ln 2}{4.47 \times 10^9}\right) = 3.29 \times 10^9 \text{ years}$$

age of sample = ... years [2]

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JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

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PHYSICS

9749/04

Paper 4 Practical

24 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: Will be announced by invigilator

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and the laboratory where appropriate in the boxes provided on the right.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

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1	
2	
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4	
Total	

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1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100 g of salt as shown in Fig. 1.1.

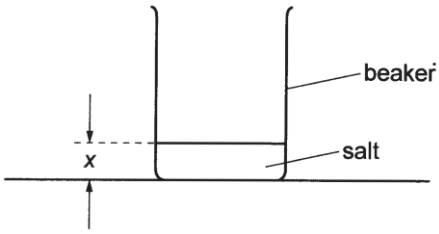

Fig. 1.1

(i) Measure and record the depth *x* of salt in beaker **P** using the vernier calipers.

$$x = \frac{1.95+1.91}{2}$$
$$x = 1.93 \text{ cm}$$

x = 1.93 cm (2 d.p.) [1]

(ii) Estimate the percentage uncertainty in your value of *x*.

$$\Delta x = 0.05 \text{ cm}$$
$$\frac{\Delta x}{x} \times 100\% = \frac{0.05}{1.93} \times 100\%$$
$$\text{percentage uncertainty} = 3\ \%$$

percentage uncertainty = 3 % (1 s.f.) [1]

(b) You have been provided with two cards. Each card has a hole of a different size.

(i) Measure and record the diameter *d* of the smaller hole.

$$d = \frac{0.33+0.33}{2}$$
$$d = 0.33 \text{ cm}$$

d = 0.33 cm (2 d.p.) [1]

(ii) Determine the area *A* of the smaller hole.

$$A = \pi(\frac{0.33}{2})^2$$
$$A = 0.086\ cm^2$$

A = 0.086 cm^2 (2 s.f.) [1]

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(c) **(i)** Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

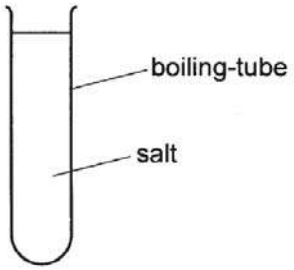

Fig. 1.2

(ii) Cover the open end of the boiling-tube with the card that has the smaller hole.

Use tape to attach the card to the boiling-tube.

The hole should not be covered by tape. When the boiling-tube is inverted, it should not be possible for salt to leave the boiling-tube other than through the hole.

(iii) Cover the hole with your finger.

Invert the boiling-tube over the empty beaker **Q**.

Remove your finger and allow the salt to flow through the hole into beaker **Q** for two minutes.

It may be necessary to shake the boiling-tube gently to achieve constant flow.

(iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level.

Measure and record the depth *y* of salt in beaker **Q**.

$$y = \frac{0.81+0.85}{2}$$
$$y = 0.83 \text{ cm}$$

y = 0.83 cm (2 d.p.)

(v) Estimate the mass *m* of salt in beaker **Q**.

Assuming that the cross-sectional area of both beakers are the same,

$$\frac{\text{mass in Q}}{\text{mass in P}} = \frac{y}{x}$$
$$m = \frac{0.83}{1.93} \times 100$$
$$m = 43 \text{ g}$$

m = 43 g (2 s.f.) [1]

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(d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker, with a hole the same size as that in **(c)(ii)**, should be inverted to apply 5 g of salt to food.

Assuming constant flow rate,

$$\frac{43\text{ g}}{\text{time needed for 43 g to flow}} = \frac{5\text{ g}}{\text{time needed for 5 g to flow}}$$

$$\text{time needed for 5 g to flow} = 5 \times \frac{120}{43}$$

$$\text{time needed for 5 g to flow} = 14\ s$$

time = ... [1]

(e) It is suggested that the rate of flow *R* of salt is proportional to the area *A* of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion. Present your measurements and calculated results clearly.

For the smaller hole

$$R_1 = \frac{43}{120} = 0.36\text{ g s}^{-1}$$

For the bigger hole, d = 0.60 cm

$$A = \pi\left(\frac{d^2}{4}\right) = \pi\left(\frac{0.60^2}{4}\right) = 0.28\text{ cm}^2$$

When t = 15 s, depth = 1.07 cm

$$\frac{m_Q}{100} = \frac{1.07}{1.93}$$

$$m_Q = 55\text{ g}$$

$$R_2 = \frac{55}{15} = 3.78\text{ g s}^{-1}$$

If R = k A, then the two experiment must yield the same k

$$k_1 = \frac{R_1}{A_1} = \frac{0.36}{0.086} = 4.2$$

$$k_2 = \frac{R_2}{A_2} = \frac{3.7}{0.28} = 13.2$$

$$\frac{k_2}{k_1} = \frac{13.2}{4.2} = 3$$

Since k_2 is three times k_1, the rate of flow of salt is NOT proportional to the area of the hole.

..... [6]

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(f) A statement found on the internet says that:

"The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However there is no manufacturing standard."

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

Use smaller holes, pepper is finer

.....

Use more holes, does not flow as freely as salt

.....

Use a mass balance to weigh the exact mass of pepper that flows out as pepper can stick to the side of beaker and height of pepper will be inaccurate.

.....

Pour the pepper carefully with the boiling tube lowered into the beaker/ Use a taller beaker /Use a cover to prevent pepper that fly out of beaker and height of pepper will be inaccurate.

..... [3]

[Total: 15 marks]

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You may not need to use all of the materials provided.

2 In this question you will investigate how the light detected by a light-dependent resistor (LDR) depends on the thickness of an absorber.

(a) (i) Connect the circuit shown in Fig. 2.1. The light-emitting diode (LED) should be connected the right way round so that light is emitted.

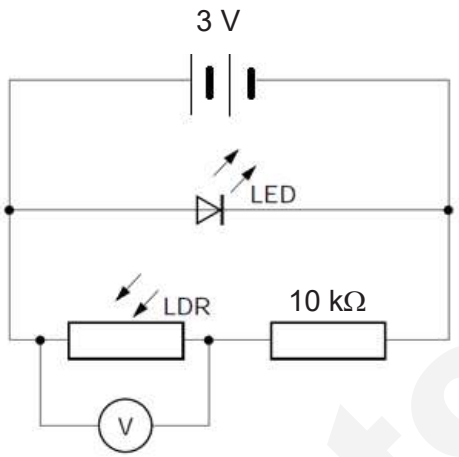

Fig. 2.1

(ii) Use the black paper and the Sellotape to make a cylinder of length 4 cm. The cylinder should fit neatly over the LDR.

(iii) Cut the cylinder in half so that you have two cylinders of length 2 cm.

(iv) Tape one cylinder over the LDR and the other cylinder over the LED as shown in Fig. 2.2.

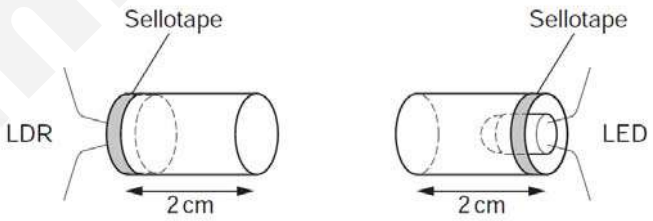

Fig. 2.2

(b) Place the cylinders together, as shown in Fig. 2.3. Record the voltmeter reading V_0.

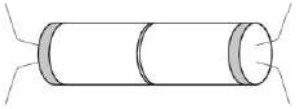

Fig. 2.3

V_0 = 1.87 V (2 d.p.) [1]

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(c) Fold the sheet of tracing paper in half four times so that you have 16 layers.

(i) Measure the thickness of these 16 layers.

x_1 / mm	x_2 / mm	$\langle x \rangle$ / mm
1.35	1.37	1.36

thickness of 16 layers = 1.36 mm (2 d.p.) [1]

(ii) Estimate the percentage uncertainty in this measurement. Show your working.

$\Delta x = 0.01$ cm (1 s.f.)

$$\text{Percentage uncertainty} = \frac{\Delta x}{x} \times 100\%$$
$$= \frac{0.01}{1.36} \times 100\%$$
$$= 0.74\ \%\ (2\ \text{s.f.})$$

percentage uncertainty = 0.74 % (2 s.f.) [1]

(iii) Determine the thickness t of one layer of tracing paper.

$$t = \frac{x}{16}$$
$$= \frac{1.36}{16}$$
$$= 0.0850\ \text{mm}$$

t = 0.0850 mm [1]

(iv) Justify the number of significant figures you have given for t.

- Since the uncertainty of the measured value of thickness of 16 layers, x, is 0.01 mm (from Part (ii)), hence x is measured to 2 decimal places (i.e. where the significant figure in Δx occurs).

- Therefore the measured value of x has 3 significant figures.

- The value of the calculated thickness of one layer, t, follows the same number of significant values as that of x (because there is no uncertainty associated with the number 16). Hence t is recorded to 3 significant figures as well. [1]

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(d) **(i)** Place four layers of tracing paper between the LED and the LDR as shown in Fig. 2.4. Record the voltmeter reading V.

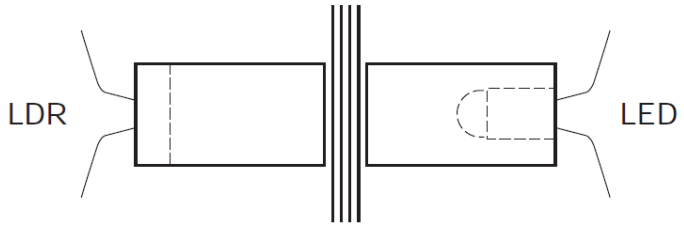

Fig. 2.4

V = 2.83 V (2 d.p.)

(ii) Repeat **(d)(i)** using eight layers of tracing paper.

V = 2.89 V (2 d.p.) [1]

(e) Explain whether your results support the idea that $V - V_0$ is proportional to the number of layers n of tracing paper.

If $V - V_0$ is proportional to n, then $V - V_0 = kn$, where k is a constant.

n	$(V - V_0)$ / V	$k = \left(\frac{V - V_0}{n}\right)$ / V
4	0.96	0.24
8	1.02	0.128

Percentage difference in the two values of k obtained

$$= \frac{|0.24 - 0.128|}{0.24} \times 100\ \%$$

$$= 47\ \%$$

Since the percentage difference in the two values of k is **more than 10 %**, k cannot be considered to be a constant, and hence the results **do not** support the idea that $V - V_0$ is proportional to n.

[2]

[Total: 8 marks]

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You may not need to use all of the materials provided.

3 In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.

(a) (i) Set up the apparatus as shown in Fig. 3.1.

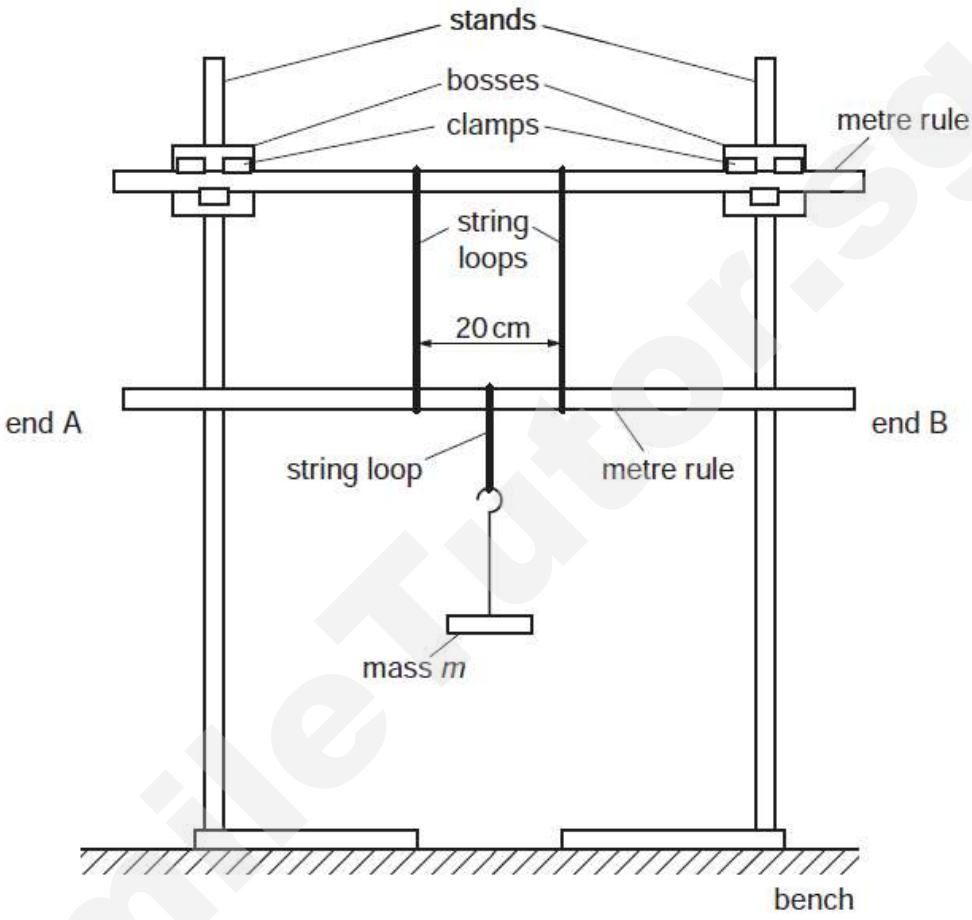

Fig. 3.1

Slide the two loops of string onto a rule and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench.

Using the string provided, make a loop of circumference 20 cm. Slide this shorter loop onto the second rule and use the longer loops to support this second rule.

Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

Use the shorter loop of string to suspend a mass m at the 50 cm mark on the second rule, where m = 0.500 kg.

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(ii) Move the end A of the lower rule towards you and the end B away from you.
Release the rule and watch the movement.
End A will move away from you and back towards you, completing a swing.
The time taken for one complete swing is T.
Determine an accurate value for T.

m/g	m/kg	N	t_1/s	t_2/s	<t>s	T/s
500	0.500	25	20.4	20.3	20.4	0.814

T = 0.814 s [1]

(b) Change m and repeat **(a)(ii)** until you have six sets of values of m and T.

m/g	m/kg	N	t_1/s	t_2/s	<t>/s	T/s	T^{-2}/s^{-2}
100	0.100	16	22.2	22.2	22.2	1.39	0.519
150	0.150	18	20.7	20.8	20.8	1.15	0.753
200	0.200	18	22.6	22.7	22.7	1.26	0.632
300	0.300	22	21.9	22.0	22.0	1.00	1.00
500	0.500	25	20.4	20.3	20.4	0.814	1.51
600	0.600	30	22.5	23.4	23.0	0.765	1.71
800	0.800	35	22.9	22.9	22.9	0.654	2.34

[7]

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(c) The quantities m and T are related by the equation

$$\frac{1}{T^2} = P\ m + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.

Plot a graph of $\frac{1}{T^2}$ against m, where P is the gradient and q is the y-intercept

$$\text{gradient} = \frac{2.20 - 0.60}{0.770 - 0.140}$$
$$= \frac{1.60}{0.630}$$
$$= 2.54$$
$$P = 2.54$$

$$\text{y-intercept} = Y - (\text{gradient})\,X$$
$$= 2.20 - 2.54\,(\ 0.770\ )$$
$$= 2.20 - 1.96$$
$$= 0.24$$
$$Q = 0.24$$

P = 2.54 kg^{-1} s^{-2}

Q = 0.24 s^{-2} [4]

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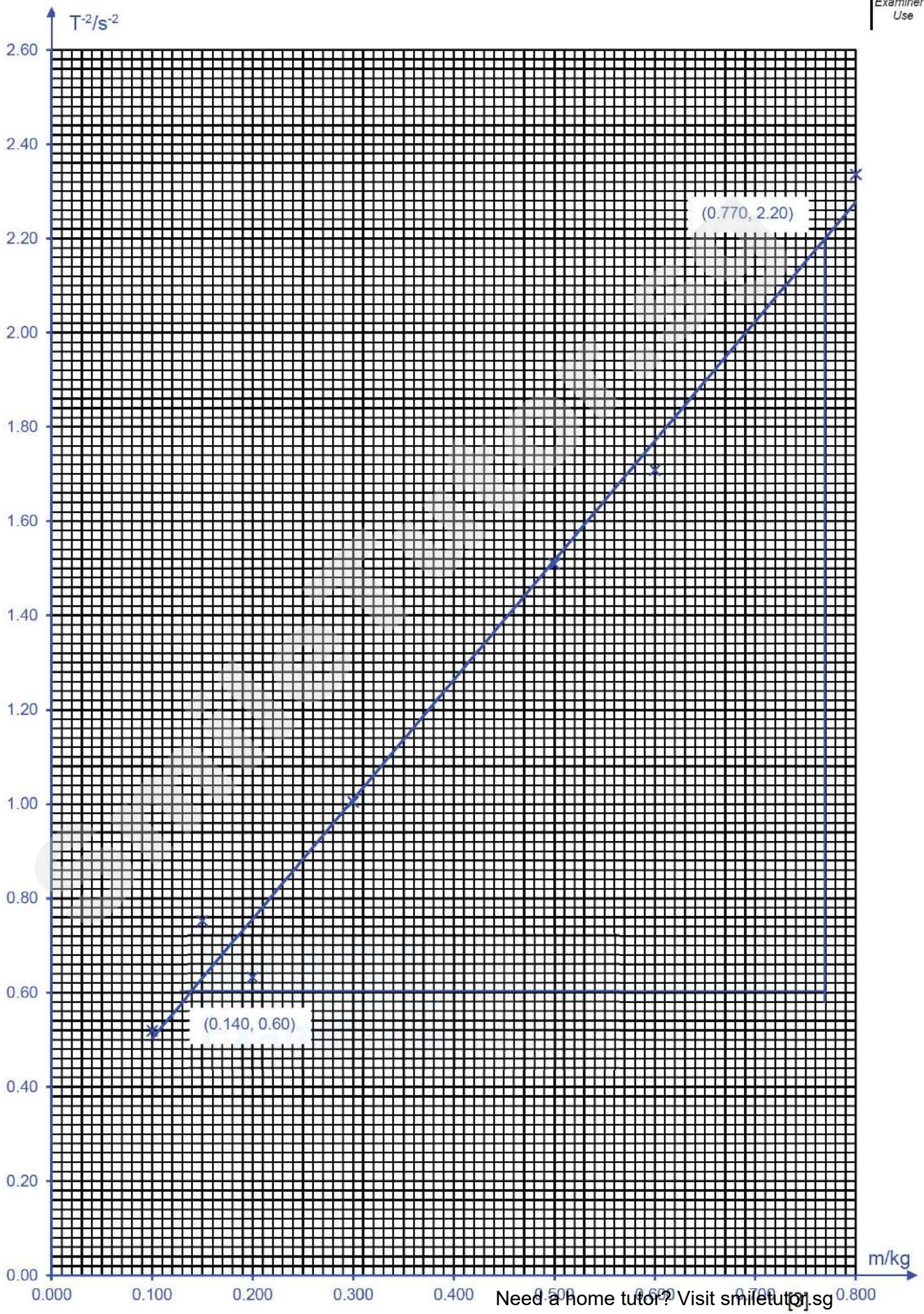

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[3]

(d) Comment on any anomalous data or results that you may have obtained.

[3]

There are no anomalous points. All data points are scattered evenly about the best fit line. Overall, the results obtained have a consistent trend.
OR
There is one anomalous point (----,-----). This point is further from the best-fit line compared to the other points.

[1]

(e) State two significant sources of errors in this experiment.

1 It is difficult to judge visually the position of the start and stop of a complete oscillation, thus affecting the accuracy of the values of t and T obtained.

2 The loops of string of 30 cm circumference are not exactly the same size, affecting the accuracy of the values of t and T obtained.

3 The rulers are not exactly horizontal, affecting the accuracy of the values of t and T obtained.

4 The loops slide on the rules during oscillations, affecting the accuracy of the values of t and T obtained.

5 The mass of the slotted masses may not be exactly what is labelled, affecting the accuracy of the m values. (In this experiment, this particular source of error is much more insignificant than the others, and may not be awarded marks in the A levels)

[2]

(f) Suggest improvements that could be made to the experiment to address the sources of error identified in **(e)**. You may suggest the use of other apparatus or different procedures.

1 Using a third retort stand, clamp a 30 cm ruler so that it points horizontally at the equilibrium position of end A of the lower ruler, to act fiducial marker for the oscillation.

2 Instead of tying a knot with the string itself, tie the knot at the correct length with a thin thread or tape at the correct length.

3 Use a spirit level to check that both rulers are horizontal, by placing the level on top of each ruler, before commencing each set of readings.

4 Tape or glue the strings to the lower rule so that they remain in the same position on the rule.

5 Use an electronic balance to measure the total mass of the mass holder and the masses before hanging each configuration of masses on the lower loop. (In this experiment, this particular source of error is much more insignificant than the others, and may not be awarded marks in the A levels)

[2]

[Total: 20 marks]

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4 A student is investigating the motion of magnets falling through a vertical copper pipe as shown in Fig. 4.1.

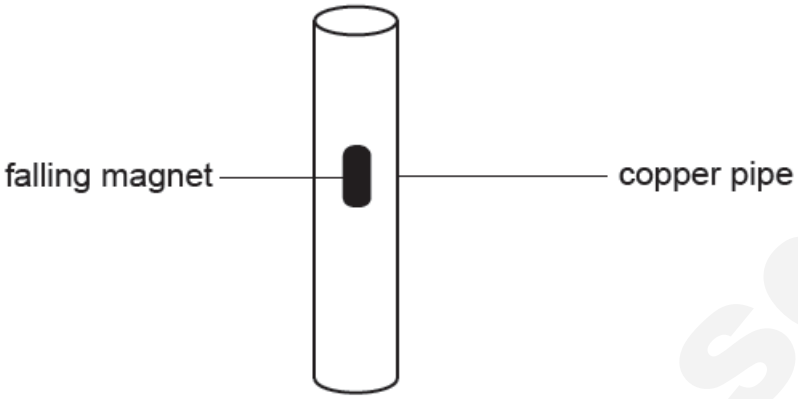

Fig. 4.1

The student releases a magnet above the copper pipe. The magnet has speed v as it leaves the pipe.

It is suggested that the relationship between v and B is

$$v = v_o e^{-\lambda B}$$

where B is the magnetic flux density at the poles of the magnet and v_o and λ are constants.

Design a laboratory experiment to test the relationship between v and B. Explain how your results could be used to determine values of v_o and λ. You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

Diagram

[Total: 12 marks]

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Suggested marking scheme

Method of data collection [4](M)

Methods/instruments to measure I.V.

- Method to measure *B*, e.g. Hall probe placed near pole of magnet. B is calculated using B=kV . (Vis the voltmeter reading as voltmeter is connected to Hall Probe)

Methods/instruments to measure D.V.

- Method to determine time at bottom of tube e.g. use of light gate(s) attached to timer

Method to vary the I.V

Method to create the condition in order to measure the I.V. / D.V. may be required.

- Labelled diagram showing a magnet and the vertical copper tube supported.

Correct positioning or connection of apparatus

- Method to ensure that copper tube is vertical, e.g. set square, spirit level, plumb line.

Method of analysis [2](A1, A2)

- Plot a graph of lnv against B and relationship is valid if the graph is a straight line.
- λ= – gradient **and v = $e^{y\text{-intercept}}$**

Additional detail (max 4)(D) and 1 mark for control variable(C)

Correct method to ensure C.V. constant/monitor C.V.

- Keep the mass of magnet constant and check it with an electronic balance.

A list of specific steps taken to taken to further improve accuracy of results or good experimental practice.

1) Adjust Hall probe until maximum reading obtained/perpendicular to field.
2) Use Hall probe to take readings for both poles and average.
3) Method to calibrate Hall probe using a known field.
4) Repeat experiment with magnets reversed and average or Repeat *v* (or *t*) for same *B* and average.
5) Mechanism to release magnet eg stop gate/string method/electromagnetic switch.
6) Distance between light gates is kept small for more accurate measurement of v.
7) The expt should not be done with external magnetic field.

Safety precautions [1](S)

- use sand tray/cushion to soften fall of falling magnet.

Marking code
M: method of data collection, A: method of analysis, C:control variable,
D: additional details, S: Safety consideration

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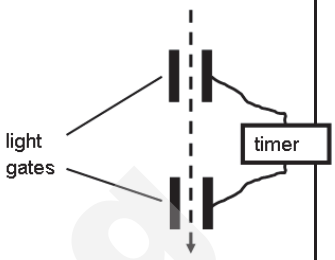
Suggested diagram



The tube and the light gates are supported by retort stands.



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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9749/01

Paper 1 Multiple Choice

13 Sep 2017

Additional Materials: Multiple Choice Answer Sheet

1 hour

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Subject Class and index number on the Answer Sheet in the spaces provided unless this has been done for you.
DO **NOT** WRITE IN ANY BARCODES.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of 13 printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ Js
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ JK^{-1}mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ JK^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	g = 9.81 ms^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

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1 Which of the following shows the base units of magnetic flux density?

A T **B** $kg\ s^{-2}\ A^{-1}$ **C** $kg\ m^{-1}\ s^{-1}$ **D** $Wb\ m^{-2}$

2 A projectile is launched at 45° to the horizontal with initial kinetic energy E.

Assuming air resistance to be negligible, what will be the kinetic energy of the projectile when it reaches its highest point?

A 0.50 E **B** 0.71 E **C** 0.87 E **D** E

3 A passenger on a bus moving forward at constant speed notices that a ball which has been at rest in the aisle suddenly starts to roll towards the front of the bus. What can be concluded about the motion of the bus from this observation?

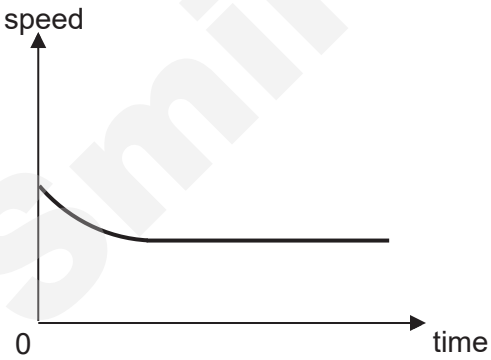
A The bus is moving at constant speed.
B The bus is decelerating.
C The bus is accelerating.
D The bus is making a turn.

4 A stream of water from a pipe travels horizontally at 10 $m\ s^{-1}$. The stream strikes a wall and splashes back horizontally at 5 $m\ s^{-1}$. What is the pressure exerted by the wall on the water? (density of water = 1000 $kg\ m^{-3}$)

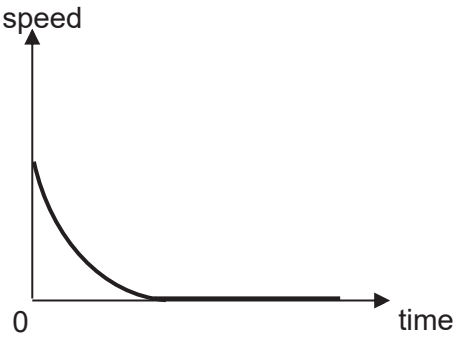
A 50 kPa **B** 100 kPa **C** 150 kPa **D** 200 kPa

5 A ball is dropped from a great height into the sea and enters the sea at high speed. The density of the ball is less than the density of sea water. If viscous force cannot be ignored, which of the following is the speed-time graph of the ball after it enters the sea?

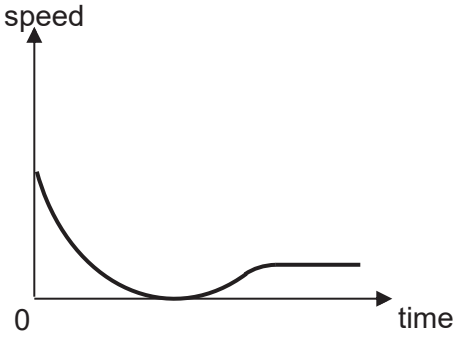
A



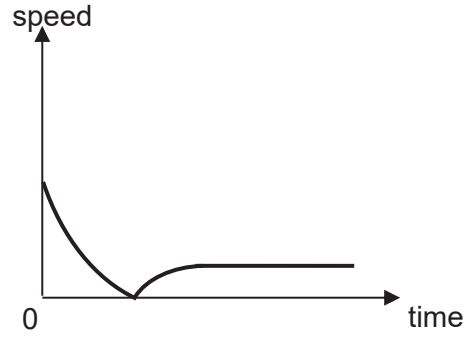
B



C



D



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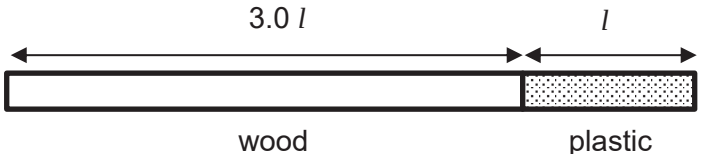
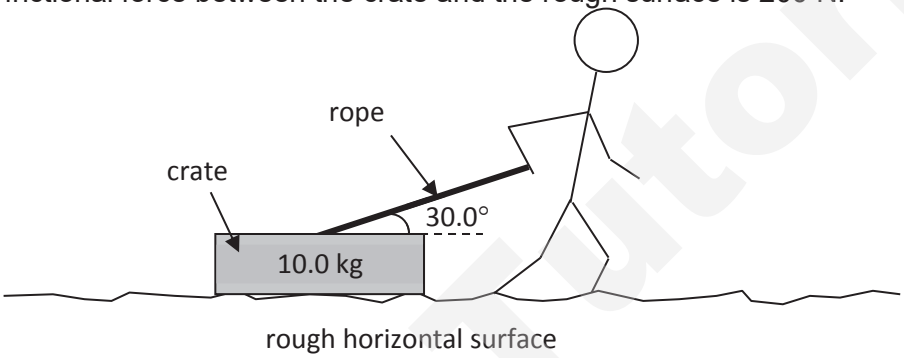
6 A rod consists of a uniform wood section and a uniform plastic section, as shown.



The length of the wooden section is 3.0 *l* and the length of the plastic section is *l*. The density of the wooden section is 600 kg m^{-3} and the density of the plastic section is 1000 kg m^{-3}. What is the distance of the centre of gravity of the entire rod from its left end?

A 1.1 *l* **B** 1.8 *l* **C** 2.2 *l* **D** 2.9 *l*

7 A man drags a crate of mass 10.0 kg across a rough horizontal surface at a constant speed of 0.800 m s^{-1}. The rope makes an angle of 30.0 ° with the horizontal. The average frictional force between the crate and the rough surface is 200 N.



What is the instantaneous power input by the man on the crate 2.00 seconds after he starts to accelerate the crate uniformly at 1.00 m s^{-2}? The angle which the rope makes with the crate remains unchanged.

A 0 W **B** 194 W **C** 588 W **D** 679 W

8 A body moves in a circle with increasing angular displacement. At time *t*, the angles θ swept out by the body are as follows:

t /s	θ /rad
2	11
4	19
6	27
8	35

The angular velocity of the body

A gradually decreases and is 4.5 rad s^{-1} when t = 6 s.
B gradually increases and is 4.5 rad s^{-1} when t = 6 s.
C is constant at 4 rad s^{-1}.
D is constant at 8 rad s^{-1}.

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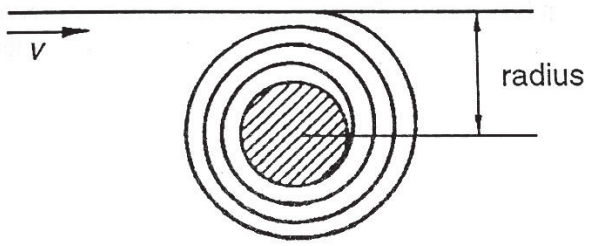
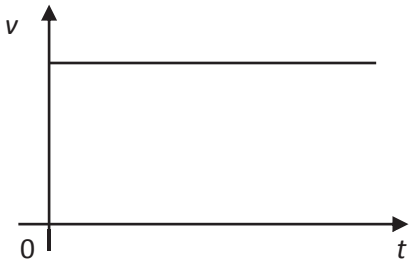
9 A straight length of tape winds on to a roll rotating about a fixed axis with constant angular velocity, the radius of the roll increasing at a steady rate.

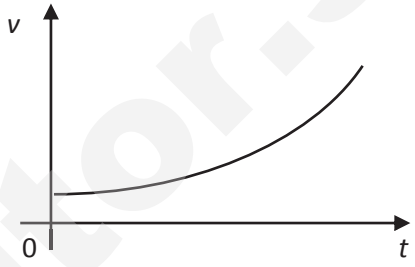


Which one of the graphs below correctly shows how the speed *v* at which the tape moves towards the roll varies with time?

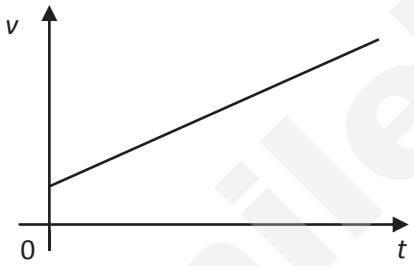
A



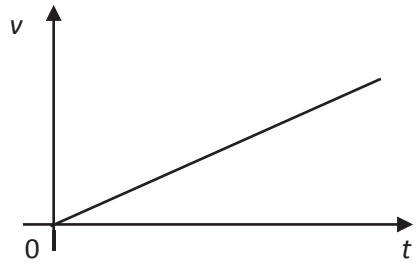
B



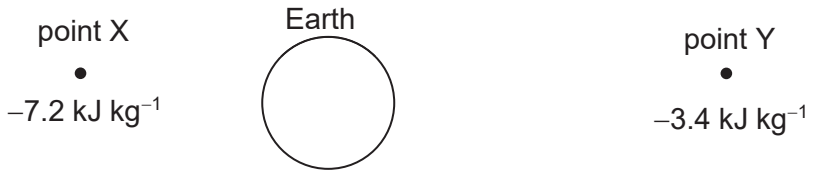
C



D



10 The gravitational potential at point X due to the Earth is –7.2 kJ kg^{-1}. At point Y, the gravitational potential is –3.4 kJ kg^{-1}.



The change in gravitational potential energy of a 4.0 kg mass when it is moved from point X to point Y is

A – 42.4 kJ **B** – 15.2 kJ **C** +3.8 kJ **D** +15.2 kJ

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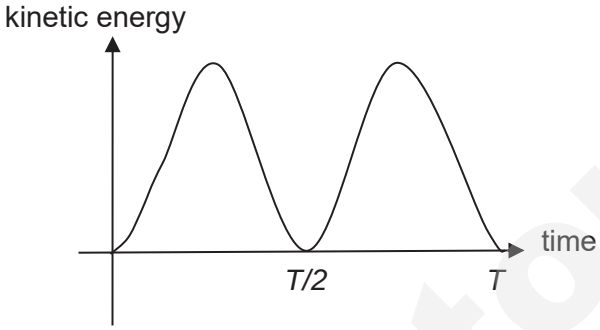
11 Why does the Moon stay in its orbit at a constant distance from the Earth?

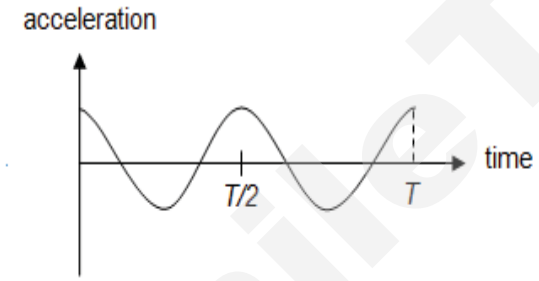
A The gravitational pull of the Earth on the Moon balances the gravitational pull of the Moon on the Earth.
B The gravitational pull of the Earth on the Moon is just sufficient to cause the centripetal acceleration of the Moon.
C The gravitational pull of the Moon on the Earth is negligible at this distance.
D The centripetal force the Earth exerts on the Moon balances the centripetal force the Moon exerts on the Earth.

12 A body moves with simple harmonic motion about a point P. The graph shows the variation with time of its kinetic energy.

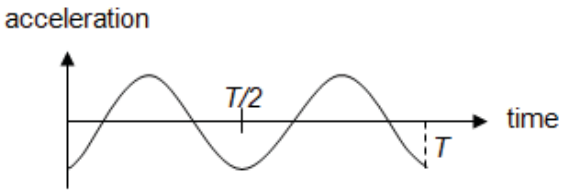


Which graph shows the variation with time of its acceleration?

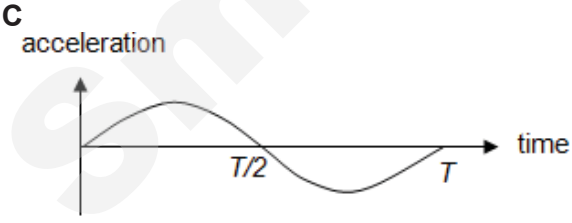
A



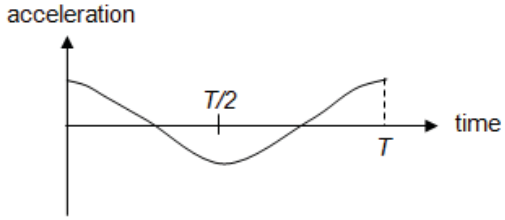
B



C



D



13 A fully loaded car's suspension system has a natural frequency of 1.20 Hz. When the car is driven over a series of equally spaced bumps at a speed of 5.0 m s^{-1}, the amplitude of vibration becomes much larger. What is the separation of the bumps?

A 1.1 m **B** 2.3 m **C** 4.2 m **D** 6.0 m

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14 For an ideal gas at 300 °C, the mean kinetic energy of the gas molecules is 1.6×10^{-23} J. What are the values for the temperature of the gas and the mean kinetic energy of the gas molecules when its molecules are, on average, travelling at twice the root mean square speed?

	Temperature / °C	Kinetic energy / J
A	600	3.2×10^{-23}
B	1100	3.2×10^{-23}
C	2000	6.4×10^{-23}
D	2300	6.4×10^{-23}

15 An ideal monatomic gas has 1000 J of heat added to it and it does 500 J of work; its temperature changes by T_1. When twice the amount of heat is added to it and it does the same amount of work, its temperature changes by T_2. The ratio of T_1 / T_2 is

A $\frac{1}{5}$ **B** $\frac{1}{3}$ **C** $\frac{3}{5}$ **D** 1

16 Which statement describes a situation when polarisation could not occur?

A Light waves are reflected.
B Light waves are scattered.
C Microwaves pass through a metal grid.
D Sound waves pass through a filter paper.

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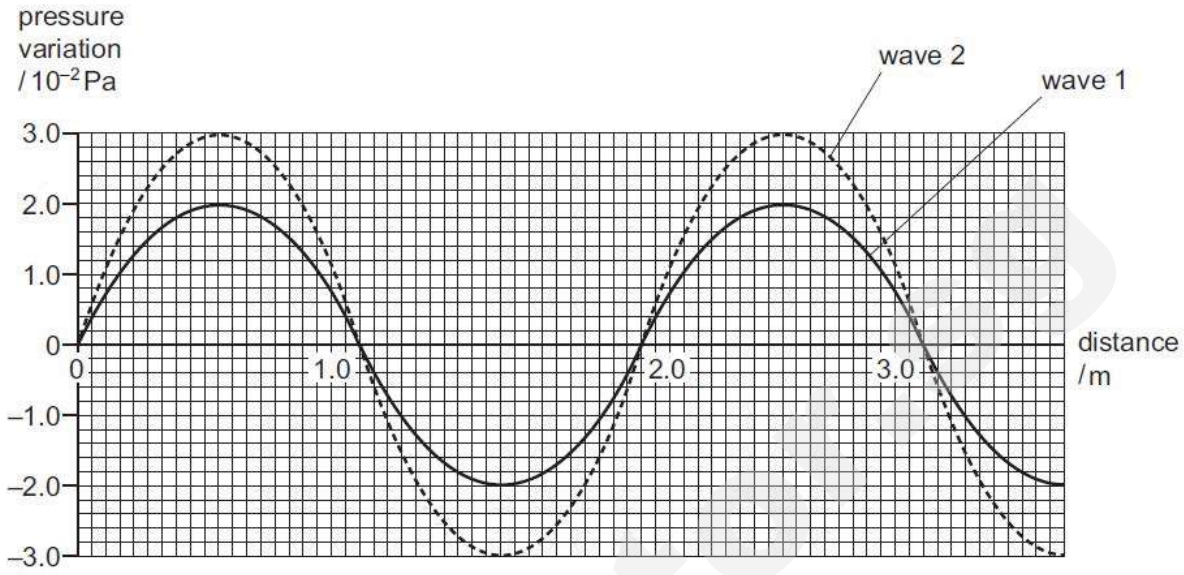
17 A sound wave consists of a series of moving pressure variations from the normal, constant air pressure.

The graph shows these pressure variations for two waves at one instant in time.



Wave 1 has an intensity of 1.6×10^{-6} W m^{-2}.

What is the intensity of wave 2?

A 2.4×10^{-6} W m^{-2} **B** 3.0×10^{-6} W m^{-2} **C** 3.6×10^{-6} W m^{-2} **D** 4.5×10^{-6} W m^{-2}

18 Monochromatic light of wavelength 590 nm is incident normally on a diffraction grating. The angle between the two second-order diffracted beams is 43°.

What is the spacing of the lines on the grating?

A 0.87 μm **B** 1.6 μm **C** 1.7 μm **D** 3.2 μm

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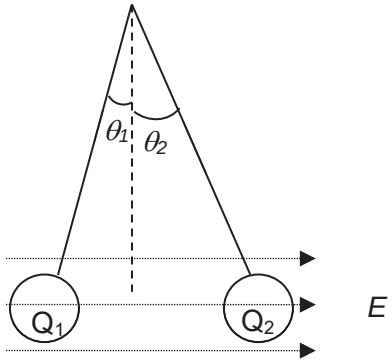
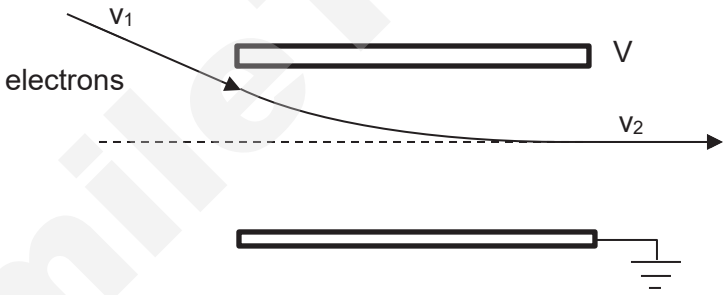
19 Two oppositely-charged spheres of the same mass are suspended by light strings. When placed in a region of uniform external electric field E, the spheres come to equilibrium as shown in the figure below, with $\theta_2 > \theta_1$.



Which statement is correct?

A Q_1 is positive and $|Q_1| > |Q_2|$.
B Q_1 is positive and $|Q_1| < |Q_2|$.
C Q_1 is negative and $|Q_1| > |Q_2|$.
D Q_1 is negative and $|Q_1| < |Q_2|$.

20 A beam of electrons move through two horizontal plates in which the electric potential of the upper plate is V. The initial speed of the electrons before entering the plates is v_1. The final velocity of the particles after leaving the plates is v_2.



Which statement is correct?

A V is positive and $v_1 > v_2$
B V is positive and $v_1 < v_2$
C V is negative and $v_1 > v_2$
D V is negative and $v_1 < v_2$

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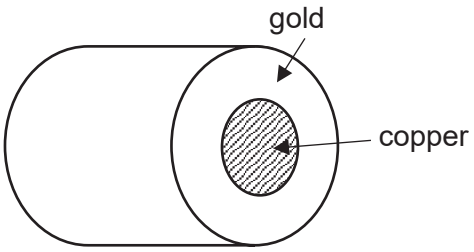
21 A composite wire of diameter 4.0 mm consists of a copper core of diameter 2.0 mm surrounded by layer of gold as shown in the figure.



The resistivity of copper is 1.7×10^{-8} Ω m and the resistivity of gold is 2.4×10^{-8} Ω m. What is the resistance of 1.0 m of the composite wire?

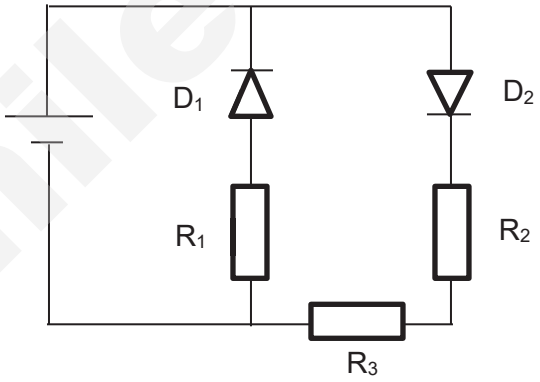
A 4.3×10^{-4} Ω **B** 1.7×10^{-3} Ω **C** 3.2×10^{-3} Ω **D** 8.0×10^{-3} Ω

22 The drift velocity of the electrons through a cylindrical metal conductor is *v* when the current flowing through the conductor is *I*.

What is the new drift velocity of the electrons if the diameter of the cylindrical conductor is doubled and the current flowing through is also doubled?

A v/2 **B** v **C** 2v **D** 4v

23 A circuit consisting of diodes and resistors is shown below.



Which of the following options correctly show the relative magnitude of the potential differences across the components D_1, R_1 and R_2?

	Greatest to smallest potential difference		
A	D_1	R_1	R_2
B	D_1	R_2	R_1
C	R_1	R_2	D_1
D	R_2	R_1	D_1

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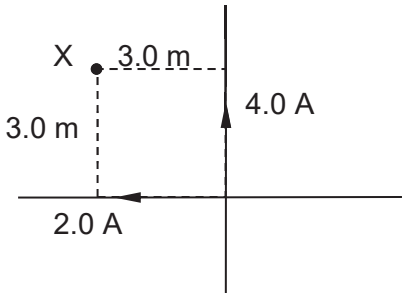
24 Two long current carrying conductors are placed perpendicular to each other. The current flowing through one of the wires is 4.0 A upwards, while the current through the other wire is 2.0 A towards the left.



What is the magnitude and direction of the resultant magnetic field at a point X, which is 3.0 m perpendicularly away from both wires? Ignore the Earth's magnetic field.

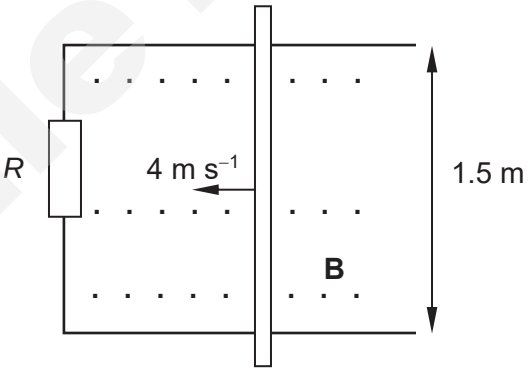
A 1.33×10^{-7} T out of the plane of the page

B 1.33×10^{-7} T into the plane of the page

C 4.00×10^{-7} T out of the plane of the page

D 4.00×10^{-7} T into the plane of the page

25 A metallic rod of length 2.5 m slides along a frictionless wire frame of width 1.5 m with a constant speed of 4.0 m s^{-1} across a magnetic flux density of 5.0 T pointing out of the plane of the frame as shown.



What is the direction of the induced current and the power dissipated by the resistor *R* of resistance 12 Ω?

	Direction of induced current	Power dissipated
A	Clockwise	208 W
B	Anti clockwise	208 W
C	Clockwise	75 W
D	Anti clockwise	75 W

26 When a steady current *I* flows in a resistance *R*, the power dissipated is *P*. If an alternating current of *r.m.s*. value *I*/2 flows in a resistance *R*/2, what is the power dissipated?

A *P** **B** *P*/2 **C** *P*/4 **D** *P*/8

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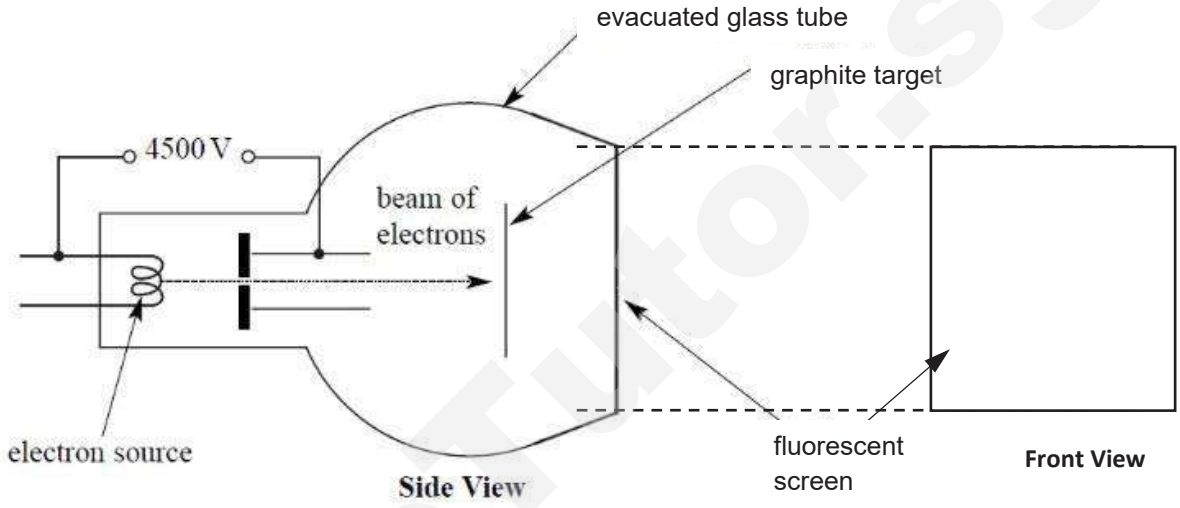
27 In a series of photoelectric emission experiments, metals of different work function ϕ were illuminated with monochromatic light of different frequencies f and intensities I. It was found that, for each experiment, the emitted electrons emerged with a spread of kinetic energies up to a certain maximum value. This maximum kinetic energy depends on

A ϕ but not on f, or I.
B ϕ and I but not on f.
C ϕ and f but not on I.
D ϕ, f, and I.

28 Electrons being fired at a polycrystalline graphite target in a vacuum as shown. The inside surface on the far side of the chamber is coated with fluorescent material that emits light when the electrons release their energy to it.



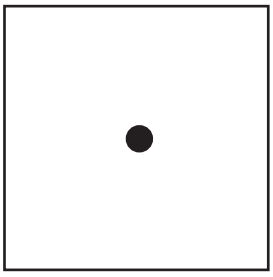
Which of the following shows the correct image seen on the fluorescent screen?

A



Front View

B



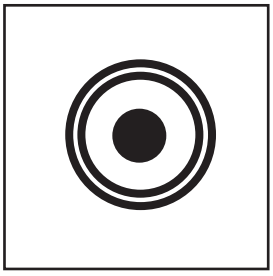
Front View

C



Front View

D



Front View

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29 Which of the following statements concerning nuclear reactions, the mass differences and energies released is true?

A The greater the binding energy of a nucleus, the more stable it is.

B If the total mass of the products of a reaction is greater, this reaction is impossible.

C Although the half-life of a radioactive substance is unaffected by changes in pressure, temperature and other external factors, we can still change the half-life by allowing the substance to react chemically to produce a new radioactive compound.

D When a stationary nucleus decays to produce a daughter nucleus and a γ-photon, the products always move off in opposite directions so as to conserve linear momentum.

30 The half-life of a certain radioactive element is such that 7/8 of a given quantity decays in 12 days. What fraction remains undecayed after 24 days?

A 1/128 **B** 1/64 **C** 1/32 **D** 1/16

-END-

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NJC P1 Answer Key

1 B	6 C	11 B	16 D	21 B	26 D
2 A	7 C	12 D	17 C	22 A	27 C
3 B	8 C	13 C	18 D	23 B	28 D
4 C	9 C	14 C	19 D	24 A	29 D
5 D	10 D	15 B	20 A	25 D	30 B

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Higher 2

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PHYSICS

Paper 2 Structured Questions

9749/02

25 Aug 2017
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answers **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 10
2	/ 10
3	/ 10
4	/ 10
5	/ 10
6	/ 10
7	/ 20
Total (80m)	

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ Js
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ JK^{-1}mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ JK^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	$g = 9.81$ ms^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

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1 **(a)** **(i)** Define the *speed* of an object.

_____

_____ [1]

(ii) Distinguish between *speed* and *velocity*.

_____

_____

_____ [2]

(b) A car is travelling along a straight road at constant speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 1.1.

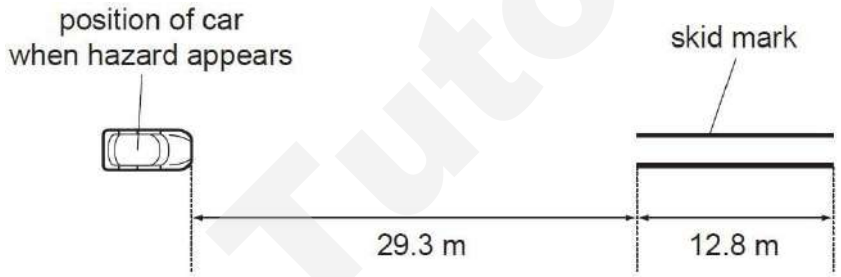

Fig. 1.1

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 g, where g is the acceleration of free fall.

(i) **(1)** Show that the speed *v* of the car before the brakes are applied is 14.6 m s^{-1}.

v = _____ m s^{-1} [2]

(2) Determine the time interval between the hazard appearing and the brakes being applied.

time = _____ s [2]

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1 **(b)** **(ii)** The legal speed limit on the road is 60 km h^{-1}. Use **both** of your answers in **(b)(i)** to comment on the driver's standard of driving.

_____

_____

_____

_____ [3]

2 **(a)** A uniform metal rod AB of mass 1.5 kg and length 0.50 m is freely pivoted at A as shown in Fig. 2.1.

The end B is suspended by a light spring. The other end of the spring is supported at X. When the rod is in equilibrium, it makes an angle of 30° with the horizontal and the angle between the rod and the spring is 90°.

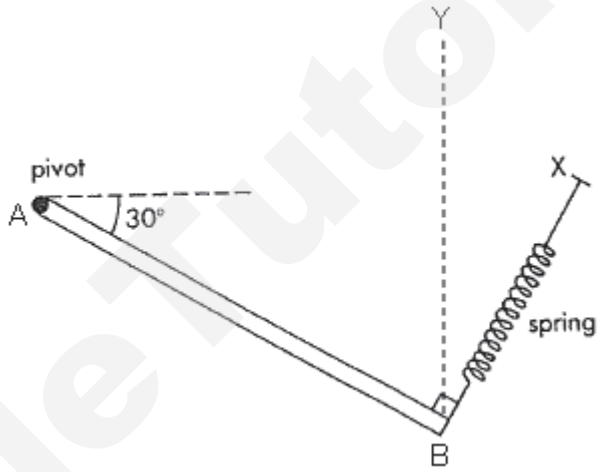

Fig. 2.1

(i) On Fig. 2.1, draw and label the forces acting on the metal rod AB. [2]

(ii) Show that the tension in the spring is 6.4 N.

[2]

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2 **(a)** **(iii)** Calculate the magnitude and direction of the reaction force at pivot A.

magnitude = _____ N [4]
direction = _____

(b) Explain if there will be any change in the tension of the spring if the spring is aligned vertically along YB instead, so that the angle between the lever and the spring is no longer 90°.

_____

_____

_____ [2]

3 On one particular ride in an amusement park, passengers 'loop-the-loop' in a vertical circle, as illustrated in Fig. 3.1.

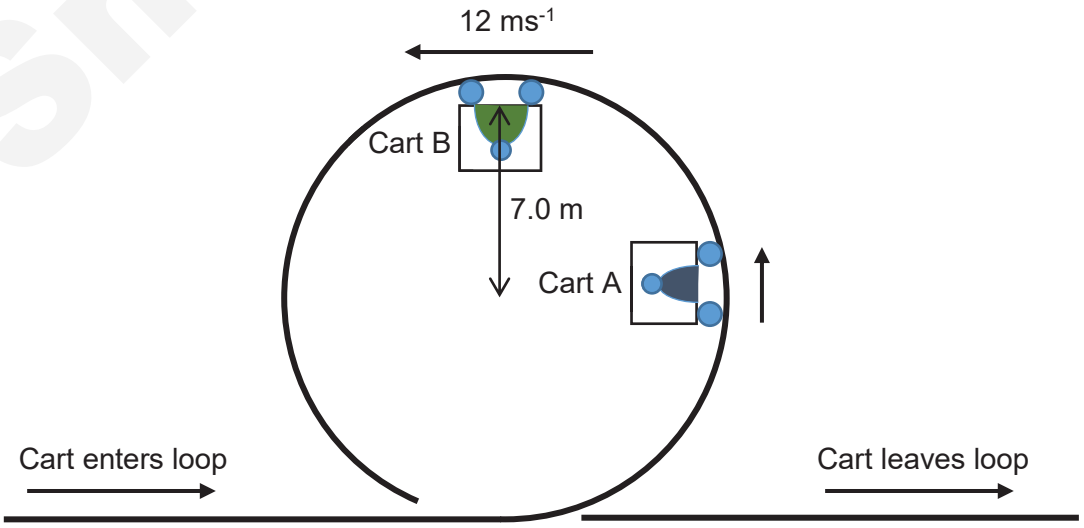

Fig. 3.1

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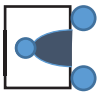
3 **(a)** **(i)** On the diagrams below, draw and label the forces acting on the passenger in Cart A and Cart B.

Cart A 

Cart B 

[2]

(b) The loop has a radius of 7.0 m and a passenger of mass 60 kg in cart B is travelling at 12 ms^{-1} at the highest point of the loop. Assume that frictional forces may be neglected,

(i) Calculate, for this passenger, at the highest point,

(1) his centripetal acceleration,

centripetal acceleration = _____ m s^{-2} [1]

(2) the force exerted by the seat on him.

force = _____ N [2]

(ii) The passenger in Cart B now moves round and descends to the bottom of the loop. Determine the speed of this passenger on leaving the loop.

speed = _____ m s^{-1} [2]

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3 **(c)** Upon seeing that the cart is moving at such a fast speed of 12 m s^{-1}, another passenger at the platform of the ride requests the operator to slow the speed of the cart down. The operator refused the request due to safety reasons. Explain in the context of this question, a reason for this.

[3]

4 A small straight tunnel is dug through the centre of the Earth as shown in Fig 4.1.

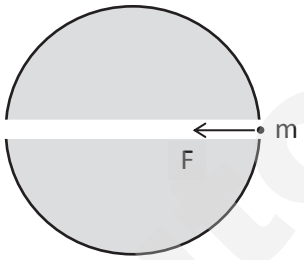

Fig 4.1

A small mass, m, released at one end of the tunnel, travels through it and emerges at the other end. Assuming that the mass does not rub against the sides of the tunnel and that air resistance is negligible, it can be shown that the gravitational force F acting on m is given by:

$$F = -\frac{4}{3}\pi G\rho x m$$

where G is the gravitational constant, ρ is the density of Earth, which is assumed to be uniform and x is the displacement of the mass from the centre of the Earth.

(a) Explain why the motion of the mass is *simple harmonic*.

[2]

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4 **(b)** The density of Earth is 5460 kg m^{-3} and the radius of Earth is 6.4 x 10^6 m.

(i) Show that the period of oscillation of the mass is 5100 s.

[2]

(ii) Calculate the maximum speed of the mass.

maximum speed = _____ m s^{-1} [2]

(c) Given that m = 1.0 kg. Show that the maximum change in gravitational potential energy of the oscillating mass is 3.1 x 10^7 J.

[2]

(d) The gravitational potential energy, E_p, of a 1.0 kg mass at Earth's surface, calculated using the formula $E_p = -\frac{GMm}{r}$, is numerically equal to 6.2 x 10^7 J. Explain why the value calculated in **(c)** is exactly half of this value.

[2]

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5 **(a)** Define *electric field strength*.

[1]

(b) Two charged spheres are placed with their centres 12.0 cm apart. Fig. 5.1 shows the resultant electric field strength between the centres of the charged spheres A and B.

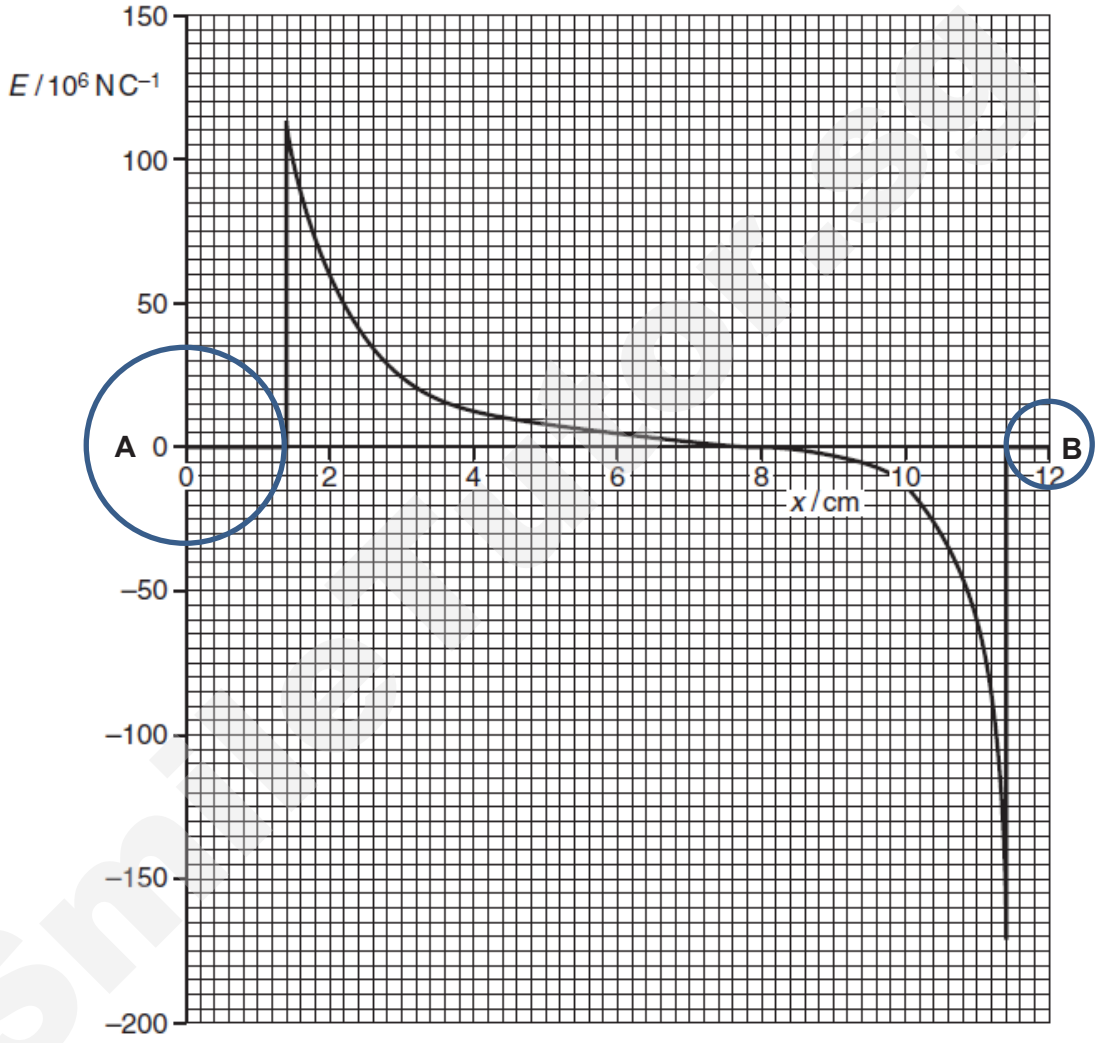

Fig. 5.1

(i) Using Fig. 5.1, state and explain the potential difference between the points x = 0.0 cm and x = 1.4 cm.

[2]

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5 **(b)** **(ii)** Calculate the ratio of the charge of sphere A to that of sphere B.

ratio = _____ [2]

(c) **(i)** A proton is moved from the point x = 8.0 cm to the surface of point B. Explain what happens to the electric potential energy of the proton.

_____

_____

_____ [2]

(ii) Estimate the change in electric potential energy of the proton when it is moved from the point x = 8.0 cm to the surface of sphere B.

change in electric potential energy = _____ J [2]

(iii) The proton is now released from rest at the point x = 6.0 cm. Describe the subsequent motion of the proton.

_____

_____ [1]

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6 **(a)** The spectrum of electromagnetic waves is divided into a number of regions such as radio waves, visible light and gamma radiation.

(i) State two distinct features of electromagnetic waves that are common to all regions of the electromagnetic spectrum.

1. _____

2. _____ [2]

(ii) State a typical wavelength for x-rays.

_____ [1]

(b) A string is stretched between two fixed points. It is plucked at its centre and the string vibrates, forming a stationary wave as illustrated in Fig. 6.1.

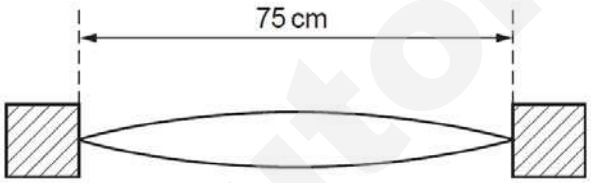

Fig. 6.1

The length of the string is 75 cm.

(i) The frequency of vibration of the string is 360 Hz. Calculate the speed of the wave on the string.

speed = _____ ms^{-1} [2]

(ii) By reference to the formation of the stationary wave on the string, explain what is meant by the speed calculated in **(b)(i)**.

_____

_____

_____

_____

_____ [3]

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6 **(c)** The setup in **(b)** is brought near a tube of water which is filled up to the brim as shown in Fig. 6.2. A tap at the bottom of the tube may be used to release the water in the tube. Determine the length of the air column when the first loud sound is heard. (Speed of sound in air = 330 m s^{-1})

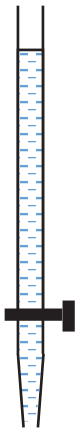

Fig. 6.2

length of air column = _____ m [2]

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7 Read the following passage and then answer the questions which follow it. (Numbers near to the right-hand margin of the passage indicate the line numbers.)

Lithium solid-state batteries

Lithium solid-state batteries represent a new concept in battery technology. Solid-state means that the liquids and pastes present in ordinary battery systems are replaced by a solid plastic film which cannot leak. This plastic film separates a lithium anode (positive electrode) from a composite cathode (negative electrode) which is in contact with aluminium foil. (See Fig. 7.1) The resultant cell can be constructed so that it has a large electrode area but is less than 0.2 mm thick. It is in many ways similar to a sheet of paper and can be cut and formed into almost any shape. Lithium solid-state cells such as this are rechargeable and can be incorporated into the cases of equipment or into such items as credit cards.

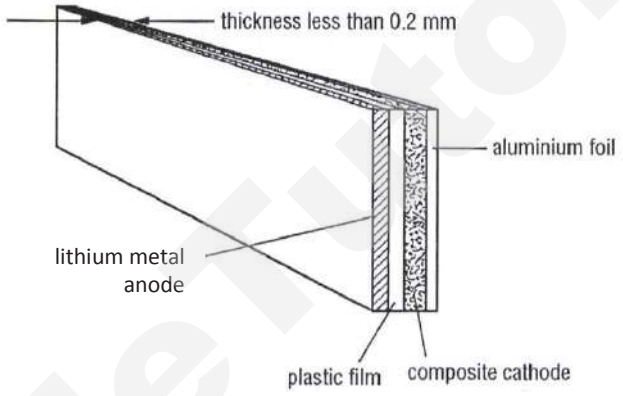

Fig. 7.1

The initial e.m.f. of the cell at full charge is 3.4 V but it rapidly falls to about 2.8 V on load and thereafter falls as shown in Fig. 7.2. The cell needs to be recharged when the e.m.f. reaches 2.0 V. In practice, its average e.m.f. is 2.5 V.

The current density, energy density and charge capacity all have to be considered for a particular application.

The recommended maximum value of discharge current density is 0.15 milliamperes per square centimetre of electrode area, the charge capacity is 3.6 coulombs per square centimetre of electrode area, and the energy density is 120 watt-hours per kilogram of cell mass.

Charging one of these cells should be carried out with a constant applied voltage of 3.4 V and with a current density limited to 2.5 mA cm^{-2}. A typical charging current against time graph is shown in Fig. 7.3 for a cell of electrode area 50 cm^2.

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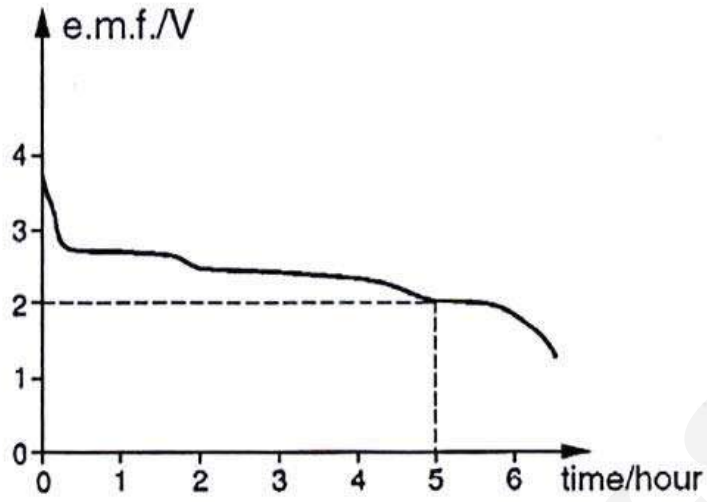

Fig. 7.2

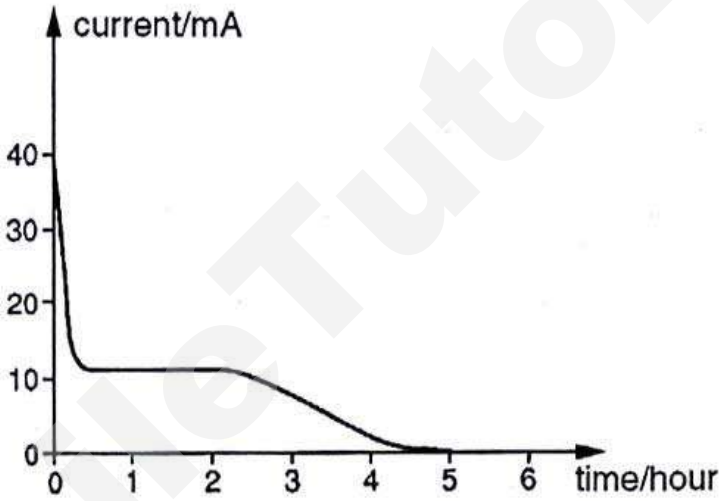

Fig. 7.3

For safety it is vital that 26

(1) cells should not be short circuited. (A fuse should be incorporated in any circuit with a cell of charge-storage capacity greater than 3600 coulombs.)

(2) cells should not be used in environments with a temperature above 140 °C.

(3) water or water vapour is kept away from lithium cells. 33

7 **(a)** Give **one** possible use of a lithium solid-state cell.

[1]

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7 **(b)** Deduce from the units, and then write down, the meaning of the terms *current density* and *energy density*. (lines 10-25)

[2]

(c) By reference to lines 10-25 of the passage, answer the following questions for a cell of electrode area 50 cm^2.

(i) Calculate the charge-storage capacity of this cell.

Charge storage capacity = _____ C [1]

(ii) Calculate the recommended maximum value of the discharge current.

Maximum discharge current = _____ mA [1]

(iii) Calculate how long this cell can supply this maximum current.

Time maximum current can be supplied = _____ s [2]

(iv) Calculate the energy it supplies in this time, assuming that the e.m.f. has a constant value of 2.5 V.

Energy supplied = _____ J [2]

(v) Estimate the mass of the cell.

Mass = _____ g [1]

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7 **(d)** Fig. 7.3 shows the charging graph for a cell of the same electrode area as in **(c)**.

(i) From the graph, estimate the average charging current over the 5-hour charging time.

Average charging current = _____ mA [2]

(ii) Calculate the energy used in charging the cell.

Energy used in charging the cell = _____ J [2]

(e) Using your answers to **c(iv)** and **d(ii)**, deduce the electrical efficiency of the charge/discharge cycle.

Electrical efficiency = _____ [2]

(f) Suggest reasons for **two** of the safety considerations. (lines 26-33)

1.

_____

2.

_____

_____ [2]

(g) Draw a diagram, using circuit symbols, to illustrate how you would connect a battery of cells which could produce a current up to 300 mA at a voltage of approximately 10 V. In your answer specify the electrode area of the individual cells.

[2]

End of Paper

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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9749/03

Paper 3 Longer Structured Questions **(Section A)**

29 Aug 2017
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answers **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 6
2	/ 10
3	/ 10
4	/ 9
5	/ 8
6	/ 8
7	/ 9
Total	/ 60

This document consists of 14 printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ Js
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ JK^{-1}mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ JK^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	g = 9.81 ms^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

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Section A (60 marks)

Answer **all** the questions in the spaces provided.

1 (a) When a solid is heated, the thermal energy required is given by the expression

gain in thermal energy = c × mass × temperature rise, where c is a constant.

(i) Name the quantities in the expression that are SI base quantities.

…… [1]

(ii) Express, in terms of SI base units, the unit of c.

unit of c = …….. [2]

(b) In an experiment to determine the specific heat capacity of a liquid by an electrical method, a student obtained the following results.

Mass of liquid heated = 1.5 ± 0.1 kg
Initial liquid temperature = 27.0 ± 0.5 °C
Final liquid temperature = 84.0 ± 0.5 °C
Electrical power of heater = 1000 ± 10 W
Time of heating = 180 ± 5 s

Calculate the specific heat capacity of the liquid together with its uncertainty. Show the method you used to determine the uncertainty.

specific heat capacity = ……..…… ± …….. [3]

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2 (a) Two balls X and Y, of the same mass 160 g, experience a head-on collision as shown in Fig. 2.1. Ball X is moving at 10 m s^{-1} and ball Y is moving at 5 m s^{-1}.

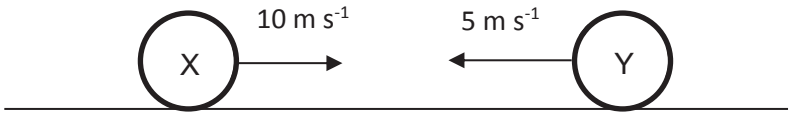

Fig. 2.1

Fig. 2.2 shows the force of ball Y on ball X during the collision.

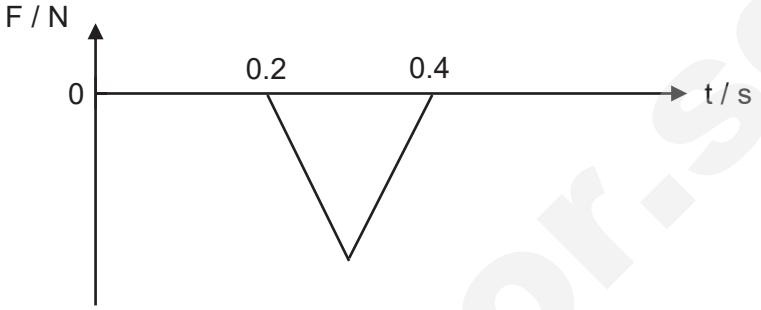

Fig. 2.2

(i) Calculate the maximum force acting on ball X if the impulse on ball X during the collision is 2.0 kg m s^{-1}.

maximum force = …….. N [1]

(ii) Calculate the velocities of ball X and ball Y after the collision. State the direction of the velocities.

velocity of ball X = …….. m s^{-1}

velocity of ball Y = …….. m s^{-1}

[3]

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2 (a) (iii) State and explain whether the collision is elastic or inelastic.

……

……

……[2]

(iv) Sketch the momentum-time graph for ball Y on Fig. 2.3. Include appropriate values.

[2]

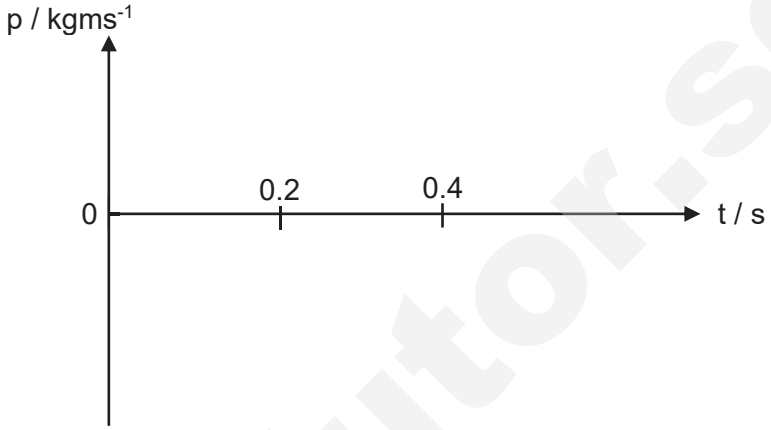

Fig. 2.3

(v) Explain whether it is possible for the kinetic energy of the balls to be fully converted to other forms of energy during the collision.

……

……

……[2]

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3 In a distant galaxy, the planet Odyssey is orbited by two small moons Scylla and Charybdis, labelled **O**, **S**, **C** respectively in Fig. 3.1 below. The distances of the moons from the centre of the planet are 5*R* and 4*R*, where *R* is the radius of the planet.

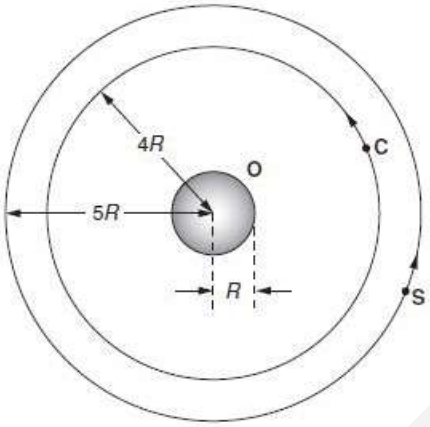

Fig. 3.1

(a) Define *gravitational field strength*.

……

……[1]

(b) Draw a gravitational field line of planet **O** passing through moon **S**. [1]

(c) The radius R of planet O is 2.0 x 10^7 m. The gravitational field strength *g* at its surface is 40 N kg^{-1}. Determine the mass of **O** assuming that the gravitational field strength due to the two moons is negligible compared to that of **O**.

mass of **O** = …….. kg [2]

(d) Calculate the increase in gravitational potential energy of a small spacecraft of mass 3000 kg when it moves from the orbit of C to the orbit of S.

increase in gravitational potential energy = …….. J [2]

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3 (e) Calculate the orbital period of **S**.

orbital period of **S** = …….. s [2]

(f) The orbits of the two moons shown in Fig. 3.1 are perfect circles. If the gravitational force exerted by **C** on **S** is significant, state and explain how the shape of the orbital path of **S** will change.

……

……

……

……[2]

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4 (a) A circuit consists of four resistors, R_1, R_2, R_3 and R_4 of the same resistance R and two ammeters, A_1 and A_2, as shown in Fig. 4.1.

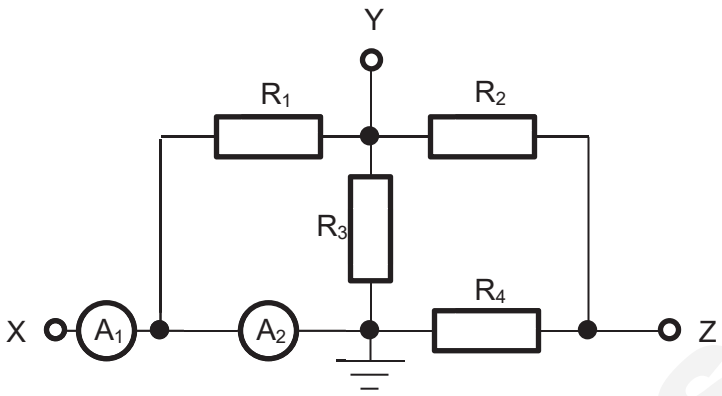

Fig. 4.1

The resistance measured between terminals X and Y is 2.4 Ω.

Show that the value of resistance R is 6.0 Ω

[1]

(b) (i) A cell of e.m.f. 1.5 V and internal resistance 0.60 Ω is connected across the terminals X and Y. Calculate the current reading in ammeter A_1.

current reading in A_1 = …….. A [1]

(ii) Calculate the current reading in ammeter A_2.

current reading in A_2 = …….. A [2]

(iii) The positive terminal of the cell is connected to X. Determine the electric potential at terminal Z.

electric potential at Z = …….. V [2]

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4 (b) (iv) An additional circuit consisting of a similar cell of e.m.f 1.5 V and internal resistance 0.60 Ω, a resistor S and a sensitive galvanometer A_3, as shown in Fig 4.2 , is now connected to the terminals X and Z.

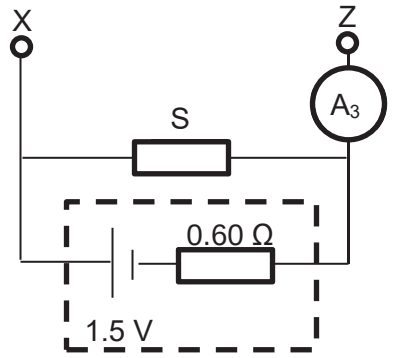

Fig. 4.2

1. The reading on galvanometer A_3 is zero. Determine the resistance of S.

Resistance of S = …….. Ω [2]

2. Explain what will happen to the reading on galvanometer A_3 when the resistance of S is increased.

……

……

…….[1]

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5 (a) The diagram below shows the **full scale** diagram of a circuit. Part of the circuit QRST is placed in a region of uniform field *B* of 0.530 T that is directed in the positive x-direction. The battery supplies a current *I* of 2.50 A. The wire experiences a force as a result.

The region of the magnetic field is represented by the shaded region.

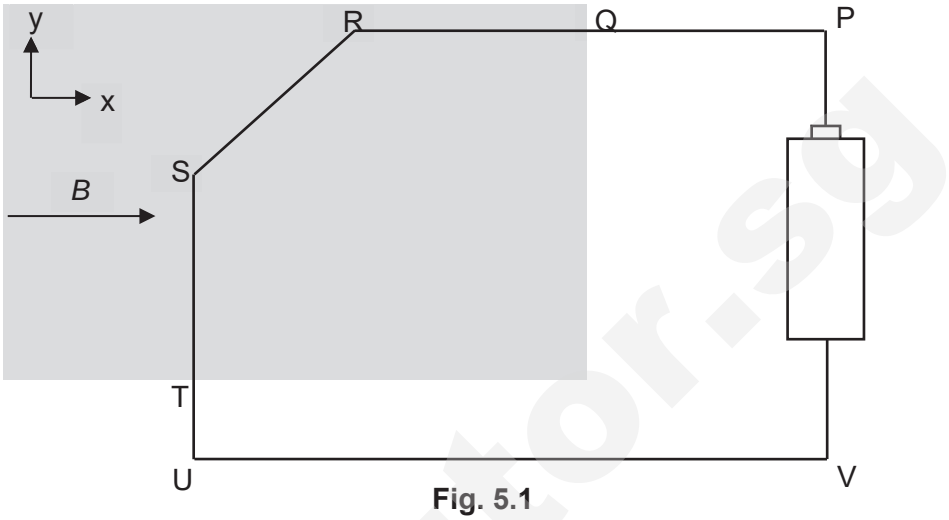

Fig. 5.1

(i) Define *tesla.*

……

…… [1]

5 (a) (ii) Calculate the resultant magnetic force acting on the wire.

resultant magnetic force = …….. N [2]

(iii) It is possible that there is no resultant force acting on the wire if the field points in one particular direction. Draw the field in this direction in the Fig. 5.1 and label it **P**. [1]

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5 (b) Fig. 5.2 shows the top view of a current balance where the rectangular wire loop PQRS pivoted at AB is in equilibrium. It is connected in series with a battery of 300 g and an e.m.f. of 2.0 V. Part of the wire loop is placed inside a solenoid. The mass of the loop can be taken to be negligible.

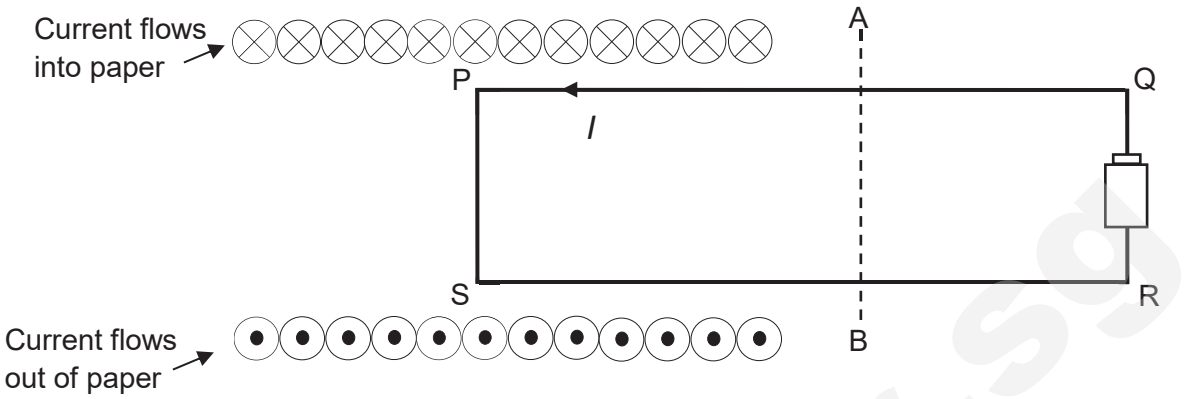

Fig. 5.2

(i) Draw the magnetic field lines in the solenoid. [1]

(ii) The length of the side PS is 6.0 cm and SB = 0.6SR. Given that the magnetic flux density in the solenoid is 0.40 T and the wire has resistance 2.0 mΩ, calculate the internal resistance of the battery.

internal resistance = …….. Ω [3]

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6 (a) Fig. 6.1 shows the front view of a large flat circular coil connected to a sinusoidal alternating voltage supply and a small flat circular coil placed at the centre of the large coil such that the planes of the two coils are coincident. The smaller coil is connected to a cathode-ray oscilloscope (c.r.o).

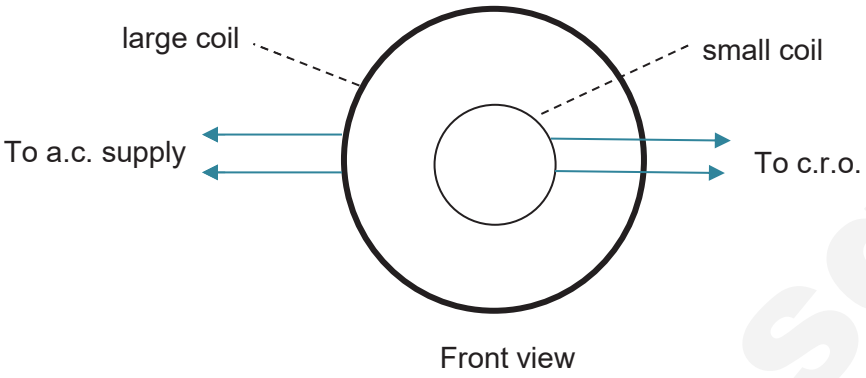

Fig. 6.1

If the variation of the sinusoidal alternating current to the large coil is as shown in Fig. 6.2, draw sketch graphs, one in each case, to show the variation with time of

(i) the magnetic flux through the small coil and [1]

(ii) the induced e.m.f. in the small coil as displayed on the c.r.o.. [1]

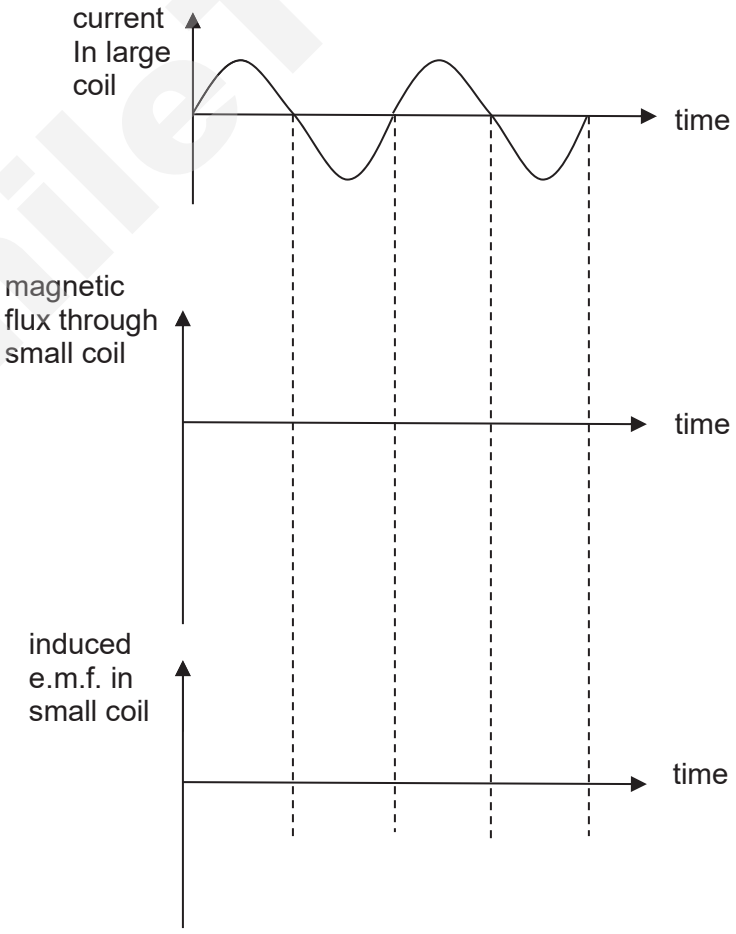

Fig. 6.2

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(b) Justify the shape of your sketches in **(a)**.

……

……

……

……[2]

(c) State and explain how the trace on the screen of the c.r.o. would be affected if the following changes are made independently

(i) the small coil is rotated such that the angle between the planes of the two coils is now 90°, whilst maintaining a constant alternating current in the large coil.

……

……

……

……[2]

(ii) the frequency of the alternating current in the large coil is increased, whilst maintaining the same amplitude.

……

……

……

……[2]

7 Experiments are conducted to investigate the photoelectric effect. It is found that if the metal surface is exposed to light, electrons are either emitted immediately or they are not emitted at all.

(a) Suggest why this observation does not support the wave theory of light.

……

……

……

……[2]

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7 (b) Data for the wavelength λ of the radiation incident on the metal surface and the maximum kinetic energy E_K of the emitted electrons are shown in Fig. 7.1.

λ /nm	E_K /10^{-19} J
650	–
240	4.44

Fig. 7.1

(i) Without any calculation, suggest why no value is given for E_K for radiation of wavelength 650 nm.

……

……

……[2]

(ii) Use data from Fig. 7.1 to determine the work function energy of the metal surface.

work function energy = …….. J [2]

(c) Radiation of wavelength 240 nm gives rise to a maximum photoelectric current I. The intensity of the incident radiation is maintained constant and the wavelength is now reduced.

State and explain the effect of this change on

(i) the maximum kinetic energy of the photoelectrons,

……

……

……[1]

(ii) the maximum photoelectric current *I*.

……

……

……[2]

END OF SECTION A

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H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9749/03

Paper 3 Longer Structured Questions **(Section B)**

29 Aug 2017
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

For Examiner's Use	
8	**/ 20**
9	**/ 20**
Total	**/ 20**

The use of an approved scientific calculator is expected, where appropriate.

Section B
Answer any **one** question.

You are advised to spend half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of 10 printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ ms^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ Js
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ JK^{-1}mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ JK^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
acceleration of free fall	g = 9.81 ms^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

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Section B (20 marks)

Answer **one** question from this Section in the spaces provided.

8 (a) A small immersion electrical heater, operating at a constant power, was used to heat 64 g of water in a thin plastic cup. The mass of the cup was negligible. The temperature of the water was recorded at regular intervals for 30 minutes and a graph of temperature against time is drawn as shown in Fig. 8.1 below.

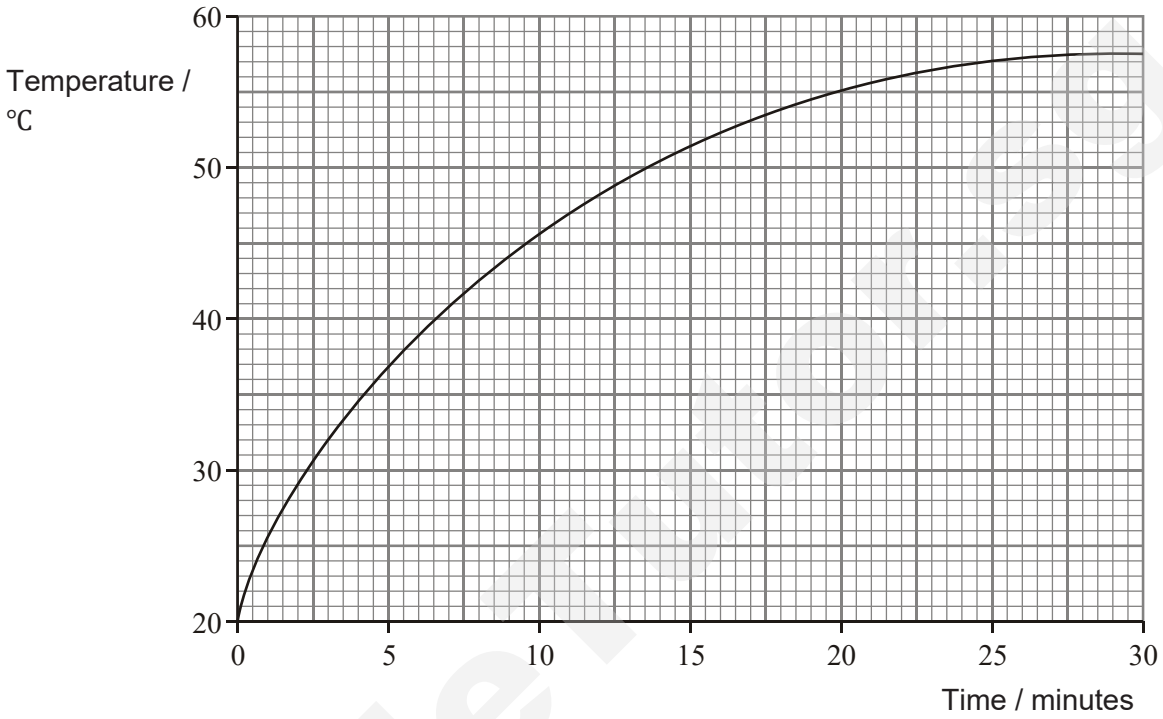

Fig. 8.1

(i) **1.** Use the graph to determine the initial rate of temperature rise of the water.

initial rate of temperature rise = …….. °C min^{-1} [2]

2. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. Determine the rate at which energy was supplied to the water by the heater.

rate of energy supply = …….. J min^{-1} [2]

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8 (a) (ii) After 26 minutes the rate of temperature rise became very small. Explain why.

……

……

……[1]

(iii) The experiment was repeated using the same mass of water in a thick ceramic mug. The initial temperature of the water was the same and the water was heated for the same length of time.

1. On Fig 8.1, sketch a possible graph of temperature against time for the water in the thick ceramic mug. [1]

2. Explain your reasoning for your graph.

……

……[1]

(b) The pressure p exerted by an ideal gas is given by the equation

$$p = \frac{1}{3}\rho\langle c^2 \rangle$$

(i) What does the symbol $\langle c^2 \rangle$ represent?

……[1]

(ii) Use the equation given above to derive an expression for the total internal energy of the molecules of an ideal gas of volume V and pressure p. [2]

(iii) Calculate the internal energy of an ideal gas of volume 3.4×10^{-4} m^3 when its pressure is 100 kPa.

internal energy = …….. J [1]

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8 (c) An ideal gas in a cylinder can be considered to undergo a cycle of changes of pressure, volume and temperature as shown on Fig. 8.2.

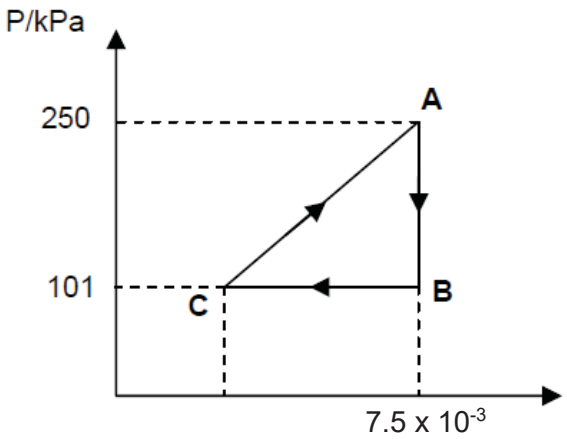

Fig. 8.2

The temperature of the gas at A and C are 623 K and 50 K respectively.

(i) Calculate the number of gas molecules in the cylinder.

no. of gas molecules = …….. [1]

(ii) Calculate the volume of gas at C.

volume of gas at C = …….. m^3 [1]

(iii) Calculate the change in internal energy of the gas for the process B → C.

change in internal energy = …….. J [1]

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8 (c) (iv) Calculate the net work done by the gas for the whole cycle.

net work done by gas = …….. J [2]

(v) Explain whether thermal energy is taken in or given out for the process C → A.

……

……

……

……[2]

(vi) State with a reason, the change in internal energy and the heat supplied to gas when it completes a cycle.

……

……

……

……[2]

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9 Nuclear reactors make use of the fission of heavy nuclides such as Uranium 235 or Plutonium 239 to produce energy. Nuclear fission takes place when a Uranium 235 or a Plutonium 239 nuclide absorbs a slow neutron and split into two fragments of roughly equal masses together with two to three neutrons and the release of vast amount of energy. A typical reaction involving Uranium 235 is represented by the equation below:

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + energy $$

The rest masses of the nuclides involved are as follows:

Nuclide	Rest mass
Uranium 235	235.0439299 u
Barium 141	140.9144119 u
Krypton 92	91.9261561 u
Neutron	1.0086649 u

Fig. 9.1

(a) Determine the energy released (in units of MeV) when a single Uranium 235 nucleus undergoes fission.

energy released = …….. MeV [3]

(b) Besides Uranium 235, the fuel rod in the nuclear reactor also contains Uranium 238. When a Uranium 238 nucleus is exposed to free neutrons, it can absorb a free neutron to form ${}^{239}_{92}U$ which then decays to ${}^{239}_{93}Np$ (first decay) and then to ${}^{239}_{94}Pu$ (second decay).

(i) Complete the following nuclear equation for the first decay. [1]

$$ {}^{239}_{92}U \rightarrow {}^{239}_{93}Np + \_\_\_\_\_ + \overline{\upsilon} $$

(ii) Suggest what does the symbol $\overline{\upsilon}$ represent.

……[1]

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9 (b) (iii) In the fuel rod, $^{239}_{93}Np$ nuclei are produced at a constant rate of 1.80 x 10^7 s^{-1}. On Fig. 9.2, draw a graph to show how **the number of $^{239}_{93}Np$ produced**, varies with time. Label this graph **X**. Assume that initially, there are no $^{239}_{93}Np$ nuclei present. [1]

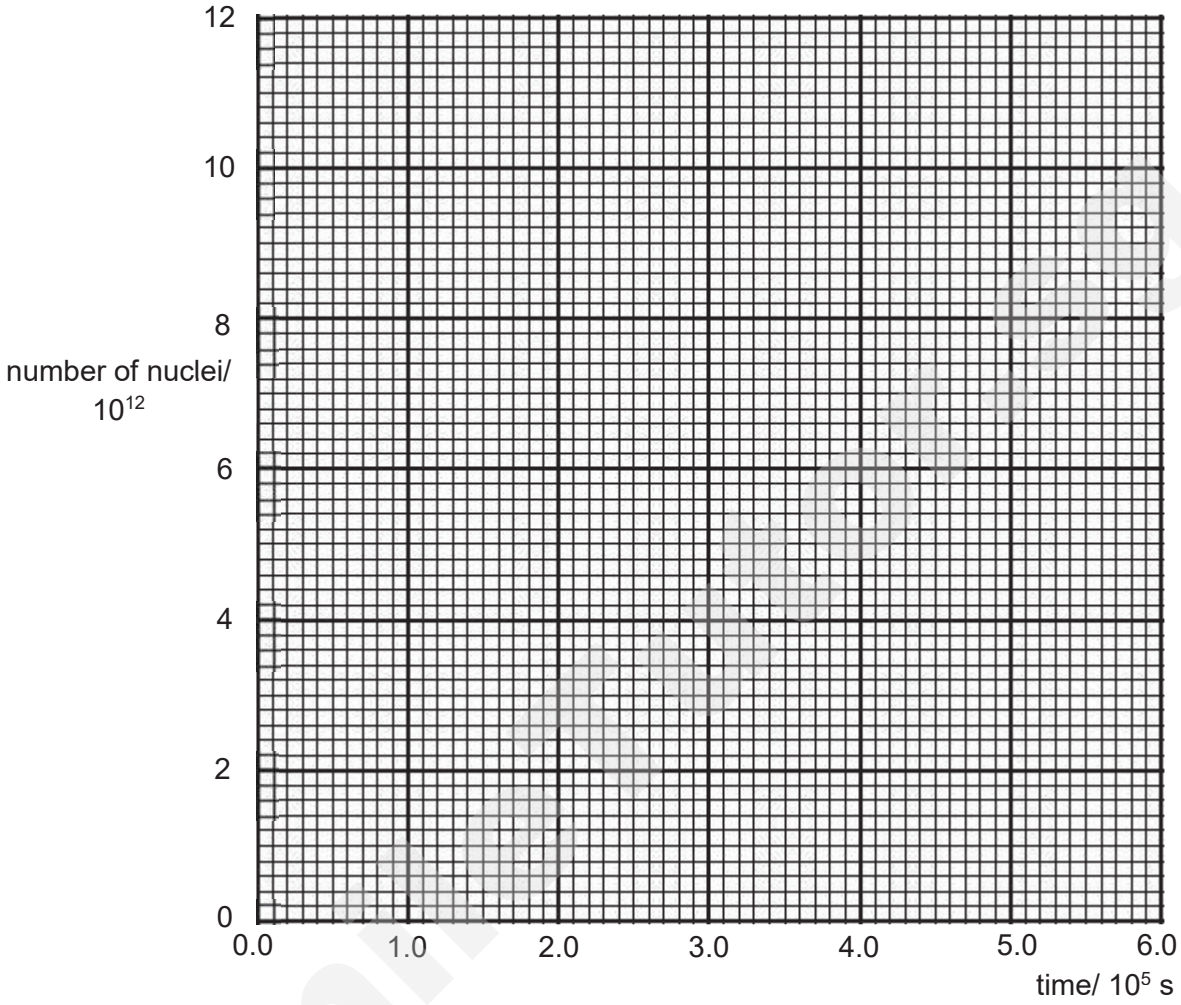

Fig. 9.2

(iv) State and explain, without calculation, how the rate of decay of $^{239}_{93}Np$ nuclei varies with time.

……

……

……[2]

(v) Explain why the number of $^{239}_{93}Np$ nuclei present eventually becomes constant.

……

……[1]

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9 (b) (vi) Calculate this constant number of $^{239}_{93}Np$ nuclei given that the half-life of $^{239}_{93}Np$ is 2.04 x 10^5 s.

constant no. of $^{239}_{93}Np$ nuclei = …….. [3]

(vii) On Fig. 9.2, sketch a graph to show how the number of $^{239}_{93}Np$ nuclei present varies with time. Label this graph **Y**. [1]

(viii) Assuming that $^{239}_{94}Pu$ is stable, determine the rate of production of $^{239}_{94}Pu$ when the number of $^{239}_{93}Np$ nuclei reaches a constant value.

rate of production of $^{239}_{94}Pu$ = …….. s^{-1} [1]

(ix) On Fig. 9.2, sketch a graph to show how the number of $^{239}_{94}Pu$ varies with time assuming that $^{239}_{94}Pu$ is stable. Label this graph **Z**. [1]

(x) $^{239}_{94}Pu$ is in fact radioactive with a half-life of 7.58 x 10^{11} s. Determine, with a suitable calculation, whether this instability has any significant effect on the shape of graph **Z** in **(ix)**.

……

……

……[2]

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9 (b) (xi) A stationary $^{239}_{94}Pu$ nucleus undergoes radioactive decay to give an alpha particle and a $^{235}_{92}U$ nucleus. The energy released in the decay is 5.16 MeV. Determine the velocity of the alpha particle immediately after the decay.

velocity of α particle = …….. m s^{-1} [3]

END OF PAPER

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NATIONAL JUNIOR COLLEGE

Preliminary Practical Examination
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

Paper 4 Practical Test
Candidate answers on the Question Paper.

No Additional Materials are required.

9749/04
15 August 2017
2.5 hours

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 15
2	/ 8
3	/ 20
4	/ 12
Total (55m)	

This document contains 13 printed pages, including this cover page.

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1 When an object falls in air, it experiences a drag force which opposes the motion of the object. Larger objects experience greater drag forces. In this experiment, you will investigate how the terminal velocity of a paper cone falling in air depends on the diameter of the cone.

(a) Cut a sector out of a piece of filter paper as shown in Fig. 1.1.

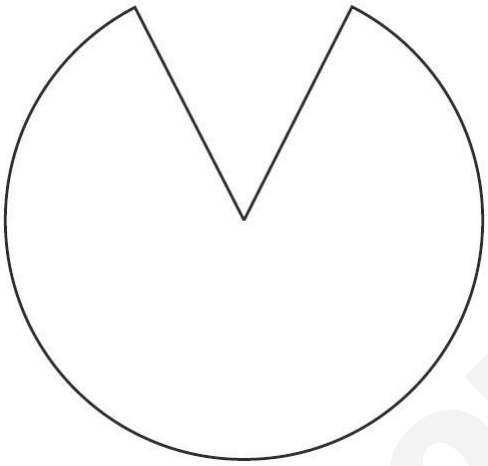

Fig 1.1

(b) (i) Tape the straight edges of the paper together to produce a cone, as shown in Fig. 1.2.

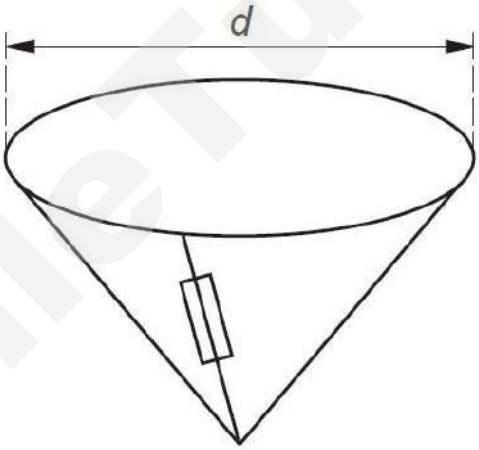

Fig. 1.2

(ii) Measure and record the diameter *d* of the cone.

d = ...[1]

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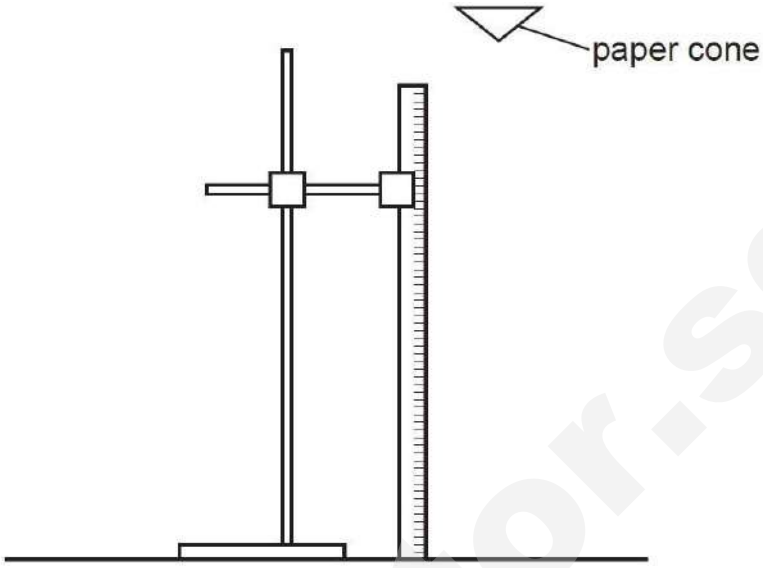
(c) (i) Mount a metre rule vertically using a stand, boss and clamp.

(ii) Release the cone from a short distance above the top of the metre rule, as shown in Fig. 2.3.



Make and record measurements to determine the time t for the cone to fall through a distance h from the top of the metre rule.

h = ...

t = ...
[2]

(d) Estimate the percentage uncertainty in t, showing your working.

percentage uncertainty in t = ...[2]

(e) Calculate the terminal velocity v of the cone.

v = ...[2]

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(f) **(i)** Remove the tape from the paper and cut away a larger sector as shown in Fig. 1.4.

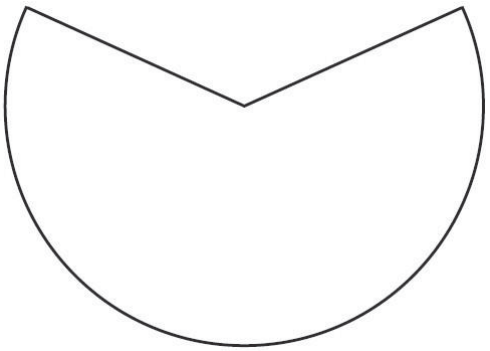

Fig. 1.4

(ii) Repeat **(b)**, **(c)(ii)** and **(e)**, recording your results below.

d = ...

h = ...

t = ...

v = ...
[2]

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(g) It is suggested that v is inversely proportional to d. Do the results of your experiment support this suggestion? State and explain your reasoning clearly.

.....

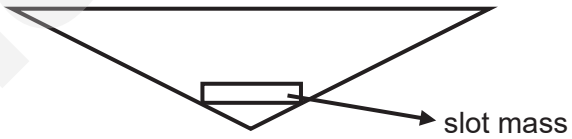
.....

.....

.....

[4]

(h) In parachute making, it is also necessary to take into account the mass of the parachutist. Suggest changes to the paper cone experiment described above to study how a mass can affect the terminal velocity of the paper cone.



.....

.....

.....

.....

.....

.....

[2]

[Total: 15 marks]

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2

This investigation considers the amount of charge flowing through a resistor.

(a) (i) Set up the circuit shown in Fig. 2.1, taking care to connect component Y the right way round.

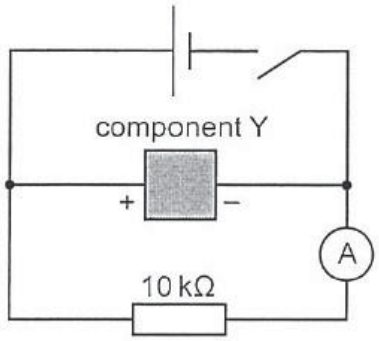

Fig. 2.1

(ii) Close the switch and wait about 10 s . Record the reading I on the ammeter.

I = ... [1]

(b) When the switch is opened, the current in the resistor gradually decreases to zero.

(i) Open the switch and start the stopwatch.

(ii) While the current is decreasing, record at least five readings of I and the time elapsed t up to a value of t = 50 s. You may need several attempts before you have a satisfactory set of results. You will need this set of readings to plot a graph in 2(c).

[2]

(iii) State two problems that arose in taking the readings.

1 .....

.....

2 .....

..... [2]

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(c) Plot your values from **(b)(ii)** on Fig. 2.2. The graph obtained should be a curve.

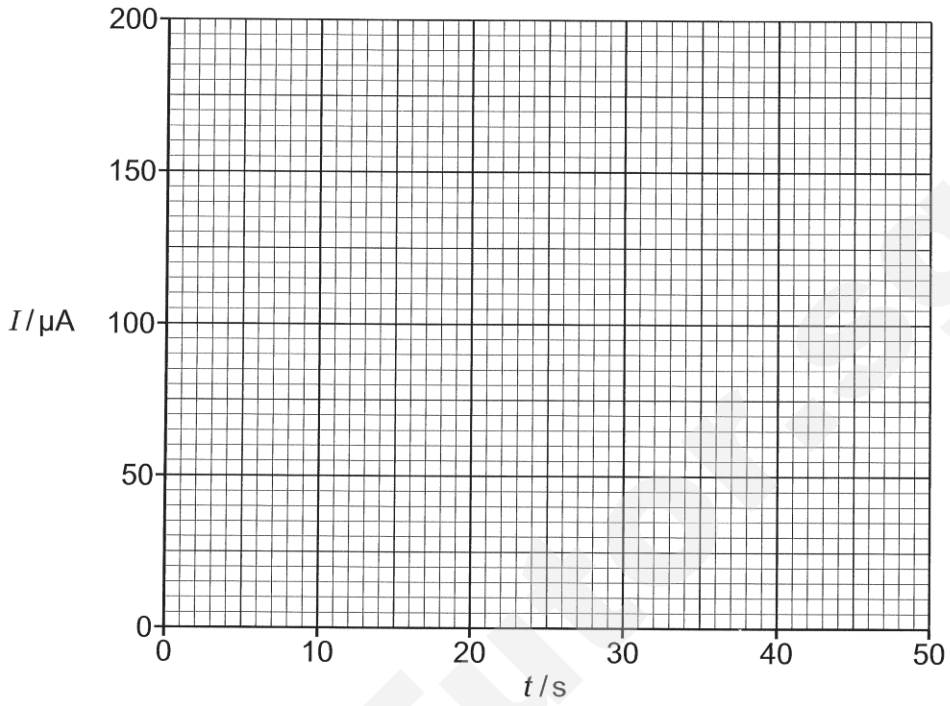

Fig. 2.2

[2]

(d) The area under the graph represents the charge Q that has flowed through the resistor during the 50 s. Estimate this charge.

Q = ... [1]

[Total: 8 marks]

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3 In this experiment, you will investigate the motion of a system of masses.

(a) Set up the apparatus as shown in Fig. 1.1, with the shorter length of string above the central loop and the longer length of string below the central loop.
Place four slotted masses in the bottom loop and four slotted masses in the central loop.

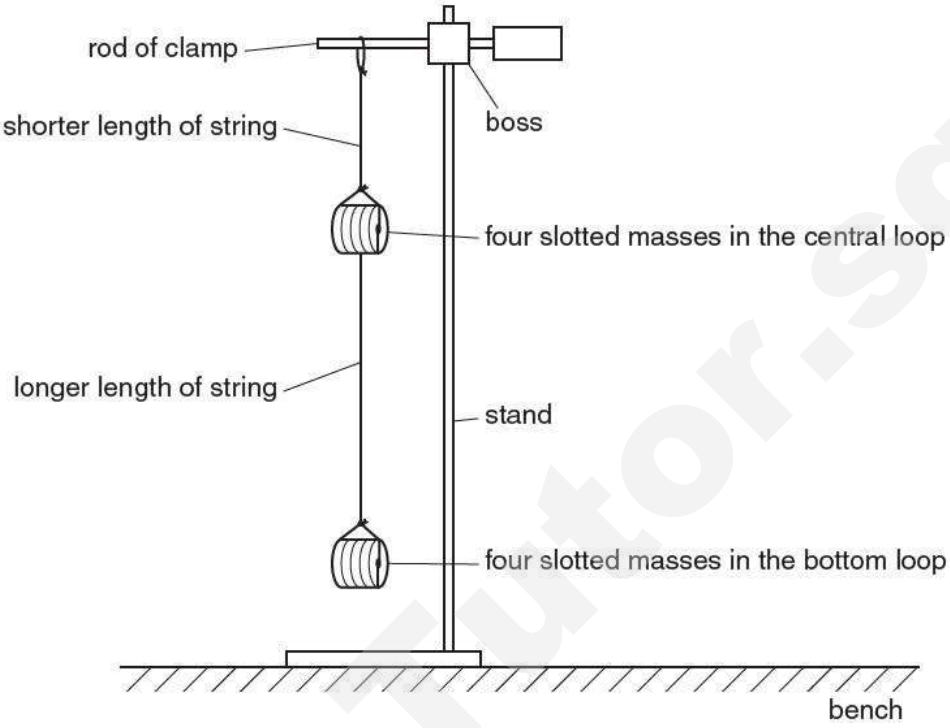

Fig 3.1

(b) Move the slotted masses in the bottom loop to the left.
Release the slotted masses and watch the movement.
The slotted masses will move to the right and then to the left again, completing a swing as shown in Fig. 3.2.

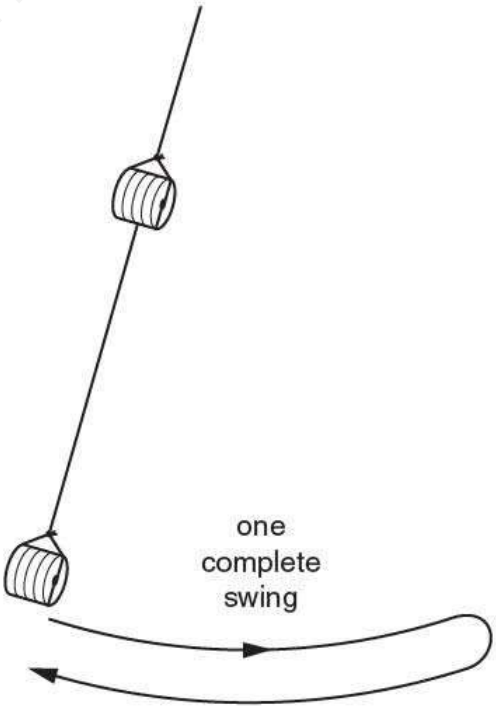

Fig 3.2

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(c) Make and record measurements so that the period T of these oscillations may be determined.

T = ... [2]

(d) Change the number of slotted masses in each loop. Use **all** the eight slotted masses.

(i) Count and record the number *B* of slotted masses in the bottom loop.

B = ...

(ii) Count and record the number *C* of slotted masses in the central loop.

C = ...

(iii) Repeat **(b)**.

T = ...

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(e) Repeat **(d)** until you have six sets of values of *B*, *C* and *T*. Include your results from **(c)** and **(d)**.

For each set of values, use all eight slotted masses.

[7]

(f) The quantities *T*, *B* and *C* are related by the equation

$$\frac{T^2}{B} = \frac{FC}{B} + G$$

where *F* and *G* are constants.

By plotting a suitable graph, determine the values of *F* and *G.*

F = ...

G = ...

[4]

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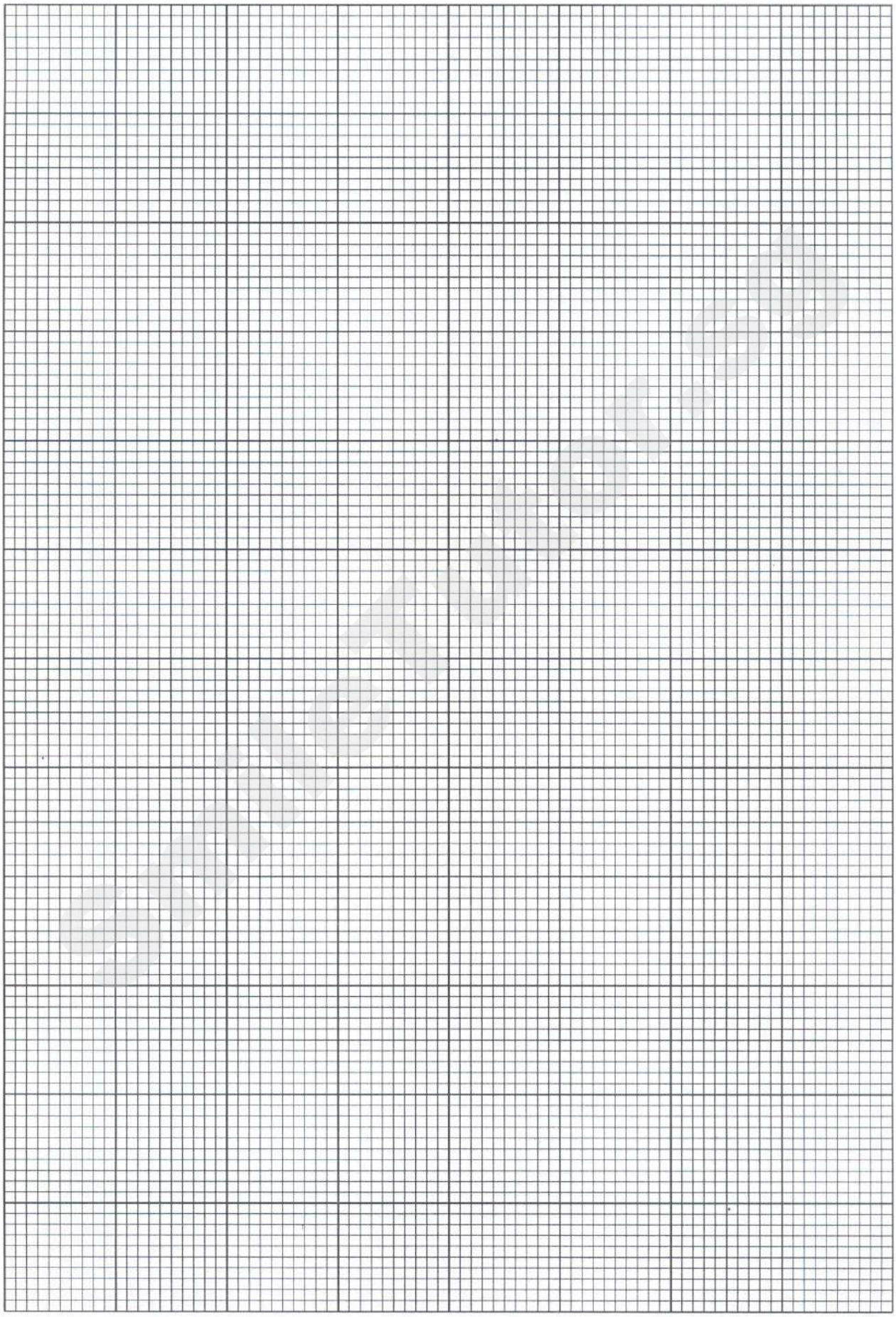

[3]

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(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

……

……

……**[1]**

(h) **(i)** State two significant error or limitation of the procedure in the experiment.

……

……

……

……

……**[2]**

(ii) Suggest an improvement that could be made to the experiment to address the error/limitation in **h**(**i**). You may suggest the use of other apparatus or different procedures.

……

……

……**[1]**

[Total: 20]

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4 A hot air balloon is tied to the ground using a rope. As the wind blows with speed *v*, the rope makes an angle *θ* to the horizontal, as shown in Fig 4.1.

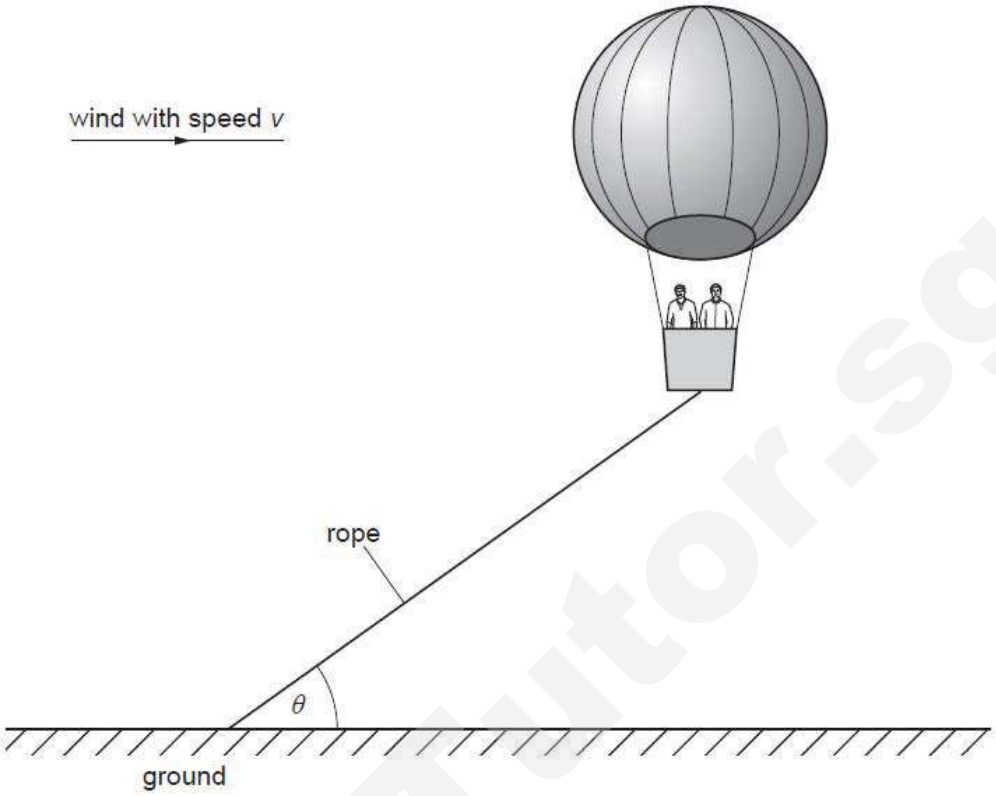

Fig 4.1

It is suggested that

$$\tan\theta = \frac{k}{v^2}$$

where k is a constant.

To model the hot air balloon in the laboratory, a balloon filled with helium is used. You may also use any of the other equipment usually found in a physics laboratory.

Design a laboratory experiment using a small helium-filled balloon to test the relationship between *θ* and *v,* and to determine a value for k.

You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(b) how the speed of the wind and angle are measured,
(c) the control of variables,
(d) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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…… [12]

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Apparatus List (Student)

Q1

1 Retort Stand with boss and clamp

2 Metre rule

3 Circular piece of filter paper

4 Scissors

5 Stopwatch

6 Sellotape

Q2

1 1.5 V dry cell in holder

2 Component Y

3 10 kΩ resistor

4 Six connecting leads

5 Stopwatch

6 Digital Multimeter

7 Switch

Q3

1 Retort Stand with boss and clamp

2 Metre rule

3 String (see diagram)

4 Eight 10 g slotted mass

5 Stopwatch

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Apparatus List

Q1

1 Retort Stand with boss and clamp

2 Metre rule

3 Circular piece of filter paper

4 Scissors

5 Stopwatch

6 Sellotape

Q2

1 1.5 V dry cell in a holder.

2 1000 μF capacitor. The capacitor should be covered in masking tape so that candidates cannot see any details printed on it. It should be labelled "**component Y**" and the polarity of the connections should be indicated with a "**+**" and a "**–**".

3 10 kΩ resistor.

4 Six connecting leads.

5 Stopwatch reading to 0.1 s or better.

6 Digital multimeter set on the 200 μA range.

7 Switch.

Q3

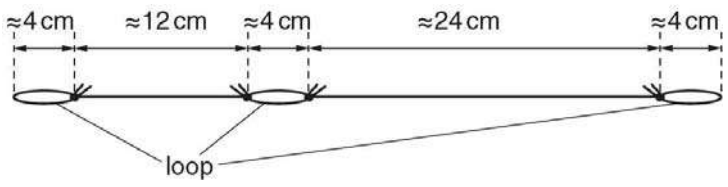
1 Retort Stand with boss and clamp

2 Metre rule

3 String (see diagram)

4 Eight 10 g slotted mass

5 Stopwatch



Each loop should be big enough to accommodate the eight slotted masses.

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2017 NJC H2Phy Prelim Paper 1 Answer Key

1 B	6 C	11 B	16 D	21 B	26 D
2 A	7 C	12 D	17 C	22 A	27 C
3 B	8 C	13 C	18 D	23 B	28 D
4 C	9 C	14 C	19 D	24 A	29 D
5 D	10 D	15 B	20 A	25 D	30 B

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1	a)	i)		Speed is the rate of change of distance travelled of an object with time.	1
		ii)		Speed is a scalar and it is only the magnitude of velocity. Velocity is a vector and it has magnitude and a stated direction.	1 1
	b)	i)	1)	$v^2 = u^2 + 2as$ $0 = u^2 + 2 \times (-0.85 \times 9.81) \times 12.8$ $v = 14.6$ m s^{-1}	2
			2)	$s = ut$ $29.3 = 14.6\ t$ $t = 2.01$ s	1 1
		ii)		60 km h^{-1} = 16.7 m s^{-1} or 14.6 m s^{-1} = 53 km h^{-1} Thus he is driving within speed limit. The driver's reaction time is too slow as compared to average human reaction time about 0.2 - 0.4 s.	1 1 1
2	a)	i)		- Weight, tension, reaction force - All 3 forces intersecting	2
		ii)		Using the principle of moments and choosing A as the pivot, Anticlockwise moment of tension = clockwise moment of weight of rod $T \times 0.50 = Wcos30° \times 0.25$ $T \times 0.50 = 1.5 \times 9.81 \times cos30° \times 0.25$ $T = 6.4\ N$	2
		iii)		Resultant force is zero hence horizontal component of reaction force is equal to horizontal component of tension. Horizontal component of reaction force = $6.4\ sin30° = 3.2\ N$ to the left Resultant force is zero hence Vertical component of reaction force + vertical component of tension = weight Vertical component of reaction force = $1.5 \times 9.81 - 6.4\ cos30° = 9.17N$ upwards Reaction force = $\sqrt{3.2^2 + 9.17^2} = 9.7N$ $tan\theta = \frac{9.17}{3.2} \rightarrow \theta = 71°$ Direction: 71° clockwise above the horizontal	1 1 1 1
	b)			The clockwise moment provided by weight remains unchanged.	1

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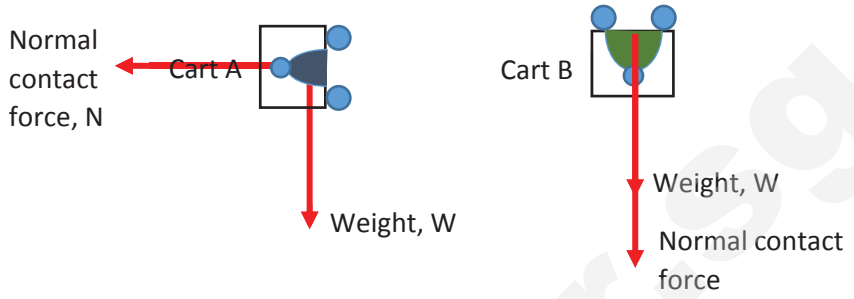
				For the rod to be in equilibrium, the net moment must zero. Since the perpendicular distance between tension and the pivot A is reduced when the tension is along YB, the tension must increase.	1
3	a)	i)			1 1
	b)	i)	1)	a_c = v^2 / r = 12^2 / 7 = 20.6 m s^{-2}	1
			2)	F_{net} = ma W + N = ma 60(9.81) + N = 60(20.6) N = 646 N	1 1
		ii)		(KE + GPE) at top = KE at bottom ½ m $(12)^2$ + mg(14) = ½ m v^2 v = 20.5 m s^{-1}	1 1
	c)			If the velocity decreases, the required centripetal force decreases as well. This would reduce the normal contact force at the top since weight cannot be reduced. The passenger would fall off the cart if contact force is reduced to zero.	1 1 1
4	(a)	The acceleration, a, of the mass is given by $a = \frac{F}{m} = -\frac{4}{3}\pi G\rho x$. Since $\frac{4}{3}\pi G\rho$ is a constant, the acceleration of the mass is directly proportional to its displacement, *x* and the negative sign shows that the acceleration is directed in the opposite direction to displacement *x*. Therefore, the motion of the mass is simple harmonic.			2
	(b)	(i)	Comparing $a = -\frac{4}{3}\pi G\rho x$ with $a = -\omega^2 x$, $\omega^2 = \frac{4}{3}\pi G\rho = \frac{4}{3}\pi \times 6.67 \times 10^{-11} \times 5460 = 1.53 \times 10^{-6}$ $T = \frac{2\pi}{\omega} = 5085 \approx 5100$ s (shown)		2
		(ii)	Maximum speed, $v = \omega x_0 = \left(\frac{2\pi}{5100}\right) \times 6.4 \times 10^6 = 7900$ ms^{-1}		2
	(c)	Maximum change in gravitational potential energy = maximum change in kinetic energy of the oscillating mass			2

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		$= \frac{1}{2}mv_{max}^2 - 0 = \frac{1}{2}(1)(7900)^2 = 3.1 \times 10^7$ J (shown)			
	(d)	The average gravitational force acting on the oscillating mass is half that of the gravitational force acting on the mass at the surface of the Earth. Since the change in gravitational potential energy is equal to the work done by gravitational force on the mass, the work done is exactly half that of the gravitational potential energy at the surface.			2
5	a)	The electric field strength at a point in an electric field is the electric force per unit positive charge acting on a small positive test charge placed at that point.			1
	b)	i)	Potential difference is zero because $E = \frac{\Delta V}{x}$ and E is zero between $x = 0$ and $x = 1.4\ cm$, hence ΔV must be zero in this region.		2
		ii)	Neutral point is at x = 8 cm $\frac{Q_A}{4\pi\varepsilon_0(8)^2} = \frac{Q_B}{4\pi\varepsilon_0(12-8)^2}$ $\frac{Q_A}{Q_B} = 2^2 = 4$		2
	c)	i)		Both A and B are positively charged. The electric potential increases from 8.0 cm to the surface of sphere B. Hence, electric potential energy increases for the proton.	1 1
		ii)		Potential difference = area under the graph About 75 small squares (each small square is $5 \times 10^6 \times 0.2 \times 10^{-2} = 10\ kV$) Potential difference = 750 kV Change in potential energy = $qV = 1.6 \times 10^{-19} \times 750\ kV = 1.2 \times 10^{16} J$	 1 1
		iii)		The proton will move back and forth around x = 8.0 cm.	1
6	a)	i)		speed of wave, transverse, can be polarized, does not require a medium to propagate,…	1
		ii)		0.01 nm to 10 nm	1
	b)	i)		wavelength = 2 x 75 cm = 150 cm v = f□ = 360 x 1.50 = 540 m s^{-1}	1 1
		ii)		When the string is plucked, it sent a wave traveling in the string. This wave hits the fixed end, gets reflected, and superpose with itself to form the stationary wave. This wave mentioned, travels at a speed that was calculated in (b)(i).	1 1 1

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	c)			v = fλ 330 = 360 x λ λ = 0.92 m since it is the fundamental mode, the length of the air column = ¼ λ = 0.23 m	1 1
7	a)			Cell-phone battery, chips on credit cards, portable charger (small, thin objects which is not use in a moist/ wet environment)	1
	b)			Current density is the current the lithium cell can provide per unit area of the lithium cell. Energy density is the total energy stored in the lithium cell per unit mass of the lithium cell.	1 1
	c)	i)		$3.6 \times 50 = 180\ C$	1
		ii)		$0.15 \times 50 = 7.5\ mA$	1
		iii)		$I = \frac{Q}{t}$ $t = \frac{Q}{I} = \frac{180}{7.5 \times 10^{-3}}$ $= 24000\ s$ [1]	 1 1
		iv)		$P = IV = 2.5 \times 7.5 \times 10^{-3} = 0.01875W$ $E = Pt = 0.01875 \times 24000 = 450J$	1 1
		v)		$m = \frac{450}{120 \times 60 \times 60} \times 1 = 1.04g$	1
	d)	i)		Average current = area / total time = (7.5+20+12.5)/5=8 mA (highly overestimate, more than 10 mA or underestimate, less than 6 mA will have marks deducted)	1 1
		ii)		$P = IV = 8 \times 10^{-3} \times 3.4 = 0.0272W$ $E = Pt = 0.0272 \times 5 \times 60 \times 60 = 490\ J$	1 1
	e)			Efficiency $= \frac{energy\ during\ charging}{energy\ during\ discharing} \times 100\%$ $= \frac{450}{490} \times 100\% = 92\%$ (ratio is also accepted)	1 1
	f)			Short circuit will lead to a large current which will cause the cell to overheat and it might spoil or even catch fire At high temperatures, the plastic film might melt and as a result charges can flow between the electrodes causing a large current which is dangerous. Water might short circuit the cell. Water is usually not pure water and so can act as a conductor. (Any 2 reasonable answers)	 2
	g)			Show 4 cells in series. Each cell will produce 2.5 V so total is 10 V. State area is 2000 cm^2 to get 300 mA.	1 1

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1	a)	i)		Mass and temperature	1
		ii)		Base units of the constant c = $\frac{\text{base units of energy}}{\text{(units of mass)(units of temperature)}}$ = $\frac{\text{kg m}^2\text{ s}^{-2}}{\text{(Kg) (K)}}$ = $\text{m}^2\text{ s}^{-2}\text{ K}^{-1}$	1 1
	b)			$Q=mc(\theta_f-\theta_i)$ $Pt=mc(\theta_f-\theta_i)$ $c=\frac{(1000)(180)}{(1.5)(84.0-27.0)}=2105$ $(\theta_f-\theta_i)=57K$, $\Delta\theta=0.5+0.5=1K$ $\Delta c=(\frac{10}{1000}+\frac{5}{180}+\frac{0.1}{1.5}+\frac{1}{57})(2105)=256.7=300$ C = 2100±300 $\text{m}^2\text{ s}^{-2}\text{ K}^{-1}$	1 1 1
2	a)	i)		The area under the force-time graph gives impulse $\frac{1}{2}(0.4-0.2)F_{max}=2\rightarrow 20\ N$	1
		ii)		Final momentum of ball X = initial momentum + impulse [1] $=0.16\times 10-2=-0.4\ kgms^{-1}$ Velocity of ball X = $-\frac{0.4}{0.16}=-2.5\ ms^{-1}$ (to the left) either correct sign or direction given Final momentum of ball Y = initial momentum + impulse $=0.16\times(-5)+2=1.2kgms^{-1}$ Velocity of ball Y = $\frac{1.2}{0.16}=7.5ms^{-1}$ (to the right)	1 1
		iii)		The initial total kinetic energy of the balls is 10 J while the final total kinetic energy of the balls is 5J. Hence there is a loss of kinetic energy. The collision is inelastic.	2
		iv)		p / kgms^{-1} 1.2 0 -0.8 0.2 0.4 t / s	2

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				Fig. 2.3 Before and after collision – straight line and correct values [1] Correct curve during collision, show that force/gradient reaches a maximum value in the center [1]	
		v)		If the kinetic energy is fully converted, the total kinetic energy is zero which implies both balls are stationary at the same time. [1] The initial total momentum of the balls is non zero (0.8 $kgms^{-1}$) [1] By the principle of conservation of linear momentum, it is not possible for both balls to be stationary as the total momentum would be zero and linear momentum would not be conserved. [1]	3
3	a)			Gravitational force per unit mass acting on a point mass placed at a point in the gravitational field.	1
	b)			Arrow pointing towards the centre of the planet	1
	c)			$\frac{GM}{(2.0 \times 10^7)^2} = 40$ M = 2.40 x 10^{26} kg	1 1
	d)			$-\frac{GMm}{5R} - \left(-\frac{GMm}{4R}\right) = \frac{GMm}{R}\left(\frac{1}{4} - \frac{1}{5}\right)$ = 40 x 2 x 10^7 x 3000 x 0.05 = 1.2 x 10^{11} J	1 1
	e)			Gravitation force provides the centripetal force $F_G = F_C$ $\frac{GMm}{(5R)^2} = m(5R)\omega^2$ $\omega = \sqrt{\frac{GM}{(5R)^3}}$ = 1.265 x 10^{-4} T = 49,700 s	1 1
	f)			The orbit of S will be elliptical because the (resultant) gravitational force acting on S from C and O, will not be equal to the centripetal force acting on S. The resultant force will points in the direction towards a non-fixed point along the line joining C and O	1 1
4	a)			Between X and Y, you have R_1, R_3 and (R_2 +R_4) in parallel. The effective resistance is $(\frac{1}{R} + \frac{1}{R} + \frac{1}{2R})^{-1} = 0.4R$ $R = \frac{2.4}{0.4} = 6.0\Omega$	1
	b)	i)		Total resistance = $2.4 + 0.6 = 3.0\Omega$ Current in A_1 = $\frac{E}{R} = \frac{1.5}{3.0} = 0.50A$	1
		ii)		Potential difference between X and Y = $\frac{2.4}{3.0} \times 1.5 = 1.2V$ Current through resistor R_1= $\frac{V}{R} = \frac{1.2}{6.0} = 0.20A$ Using Kirchoff's current law, current in A_2 = $0.50 - 0.20 = 0.30\ A$	1 1

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		iii)		Potential difference across $R_4 = \frac{6.0}{6.0+6.0} \times 1.2 = 0.6V$ Potential at Z = $0 - 0.6 = -0.6V$	1 1
		iv)	1.	As reading is zero, the potential difference across S is 0.6 V. The potential difference across S = $\frac{S}{S+0.60} \times 1.5 = 0.6$ V Hence S = 0.4 Ω	1 1
			2.	The potential difference across S will be higher. As this potential difference is larger than that of the potential difference across X and Y, a (negative) reading will be registered on the galvanometer.	1
5	a)	i)		Tesla is the unit of magnetic flux density. One tesla is the magnetic flux density if a force of 1 N acts on a wire of length 1 m, carrying a current of 1 A placed perpendicular to the magnetic field.	1
		ii)		Resultant force = BIL = (0.530)(2.50)(0.046) =0.06095 = 6.10 x 10^{-2} N	 1 1
	b)	i)		Draw a magnetic field line parallel to line SR.	1
		ii)		Using the Principle of Moments and taking moments about AB, $Clockwise\ \ Moments = Anticlockwise\ \ Moments$ $F_B(L_{SB}) = W(L_{BR})$ $(BIL_{PS})(L_{SB}) = mgL_{BR}$ $(0.40)(I)(0.060)(0.6SR) = (0.300)(9.81)(0.4SR)$ $I = 81.75A$ $E = IR_T$ $2.0 = (81.75)(r + 0.002)$ $r = 0.0225\Omega$	1 1 1

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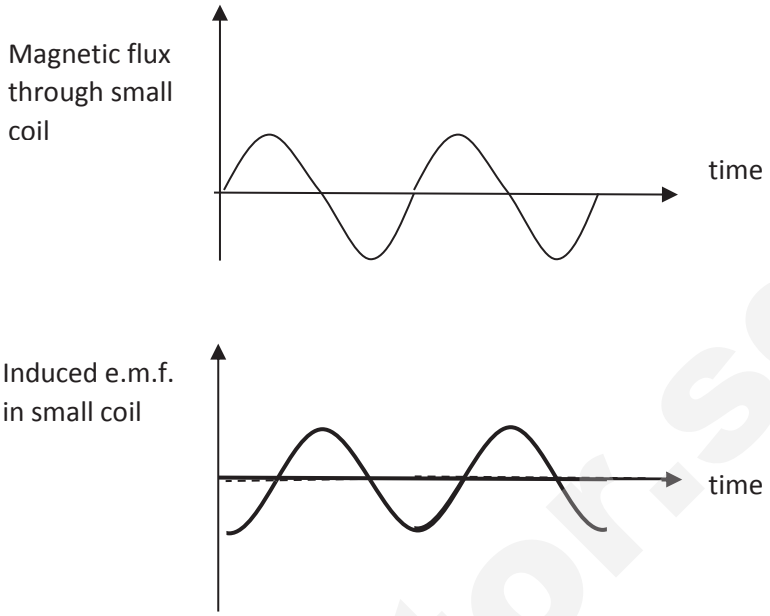
6	a)				1 1
	b)			Magnetic flux through the small coil is proportional to the magnetic flux density generated by the large coil which is proportional to the alternating current in the large coil. Hence the magnetic flux-time graph through the small coil has the same shape as that of the current-time graph for the large coil. Induced e.m.f. in the small coil is directly proportional to the rate of change of magnetic flux linkage which is obtained from the negative of the slope of the magnetic flux- time graph.	1 1
	c)	i)		When the planes of the two coils are at 90° to each other, the magnetic field due to the current in the large coil is parallel to the plane of the small coil. Hence there is no magnetic flux linkage with the small coil and no e.m.f. will be induced in the small coil. The trace on the c.r.o. will show the amplitude of the induced e.m.f. reduced to zero. A horizontal line will be seen on the screen.	1 1
		ii)		When the frequency of the alternating current in the large coil is increased, the frequency of the alternating emf in small coil will also increase and hence the period will reduce. The rate of change of flux linkage in the small coil is faster now and hence the induced emf in the small coil will increase. The trace on the c.r.o. will show number of cycles increased and induced emf with larger amplitude.	1 1
7	a)			Wave theory suggest that it will take a while for electron to gather enough energy to be liberated; but this observation shows that electrons are emitted immediately.	1

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				This also mean that once the electron gather enough energy, it will definitely be liberated; but this observation shows that sometime, photoelectron is not emitted at all.	1
	b)	i)		The larger the wavelength, the lower the frequency, thus the lower the energy, since E=hf . If the energy of the photon (650 nm) with frequency smaller than the threshold frequency, no photoelectron will be emitted. Therefore no value recorded for max KE.	1 1
		ii)		$hc / \lambda = \varphi + E_{MAX}$ $(6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (240 \times 10^{-9}) = \varphi + 4.44 \times 10^{-19}$ $\varphi = 3.8 \times 10^{-19}$ J	1 1
	c)	i)		Wavelength of the radiation is reduced, so the frequency is increased, thus the photon's energy, that is total energy, increases. Work function being constant, this will result in higher KE.	1 1
		ii)		Total energy per photon increase, but for intensity remain constant, number of photon per unit time must have decreased. This will result in less photoelectron per unit time, thus current decreased.	1 1
8	(a)	(i)	1.	Initial rate of temperature rise = gradient of the tangent to t = 0. Acceptable values: 8 to 16 °C min^{-1}	
			2.	From Q = Pt = mc$\Delta\theta$ $P = mc\frac{\Delta\theta}{t} = 64 \times 10^{-3} \times 4200 \times 8 = 2150$ J min^{-1}	
		(ii)	Rate of thermal energy supplied to the water by the heater is equal to rate of thermal energy lost to the environment.		
		(iii)	1.	Curve with the same initial gradient as the original one but lies above the original one.	
			2.	Thick ceramic cup is a better thermal insulator, hence reducing the rate of thermal energy lost to the environment resulting in the temperature of the water rising at a faster rate.	
	(b)	(i)	Mean square speed of the gas molecules.		
		(ii)	From $p = \frac{1}{3}\rho\langle c^2\rangle$ $= p = \frac{1}{3}\left(\frac{M}{V}\right)\langle c^2\rangle$ where M is the total mass of the gas & V is the volume occupied by the gas. $M\langle c^2\rangle = 3pV$		

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			Since internal energy U of an ideal gas is equal to the total random kinetic energy of the gas molecules which is $= \frac{1}{2}M\langle c^2\rangle$, we have $U = \frac{1}{2}M\langle c^2\rangle = \frac{3}{2}pV$	
		(iii)	$U = \frac{3}{2}(100 \times 10^3)(3.4 \times 10^{-4}) = 51$ J	
	(c)	(i)	From $pV = NkT$, $N = \frac{pV}{kT} = \frac{250\times10^3\times7.5\times10^{-3}}{1.38\times10^{-23}\times623} = 2.18 \times 10^{23}$	
		(ii)	From $pV = NkT$, V$= \frac{NkT}{p} = \frac{2.18\times10^{23}\times1.38\times10^{-23}\times50}{101\times10^3} = 1.49 \times 10^{-3}$ m^3	
		(iii)	$\Delta U = \frac{3}{2}p_cV_c - \frac{3}{2}p_BV_B = -911$ J	
		(iv)	Net work done $= \frac{1}{2}(7.5 - 1.49) \times 10^{-3} \times (250 - 101) \times 10^3 = 448$ J	
		(v)	Gas gains internal energy since the temperature increases and negative work is done on the gas since the volume increases. From the first law of thermodynamics, thermal energy must be taken in by the gas.	
		(vi)	No change in internal energy since the change in internal energy is state dependent and the gas returns to its initial state after one cycle. Since net work done on the gas is negative, q must be positive meaning there is net thermal energy supplied to the gas.	
9	(a)	Rest energy of the reactants = (235.0439299 + 1.0086649)uc^2 = 3.526 626 x 10^{-8} J Rest mass energy of products = (140.9144119 + 91.9261561 + 3 x 1.0086649)uc^2 = 3.523 846 x 10^{-8} J Energy released = 3.526 626 x 10^{-8} – 3.523 846 x 10^{-8} = 2.78 x 10^{-11} J = 174 MeV		
	(b)	(i)	Decay 1: $^{239}_{92}U \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}e + \overline{\upsilon}$	
		(ii)	Anti-neutrino (accept neutrino)	
		(iii), (vii) & (ix)		

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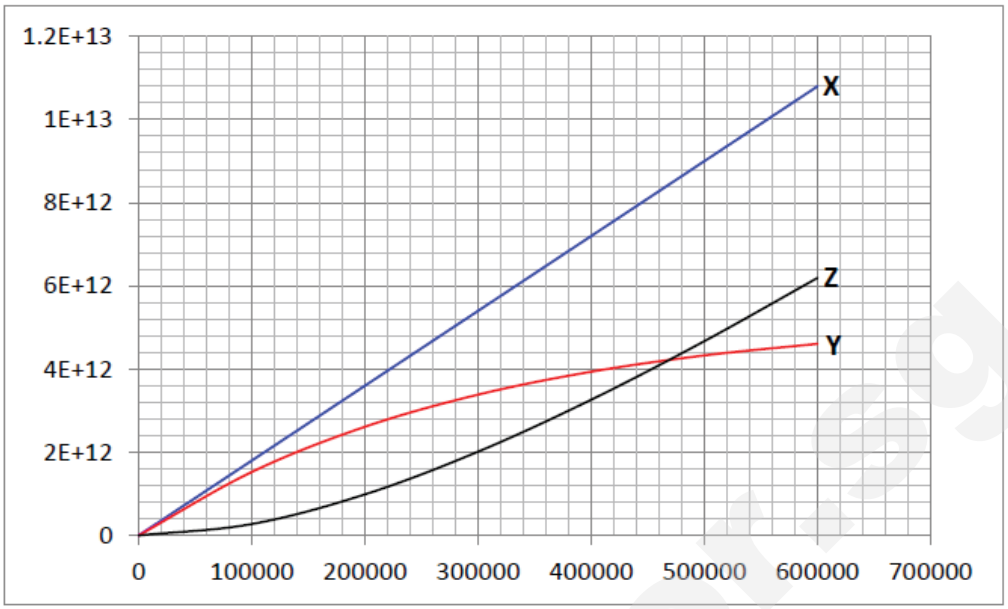

(iv)	The rate of decay increases with time because the rate of decay is proportional to the number of $^{239}_{93}Np$ nuclei present.
(v)	The number of $^{239}_{93}Np$ becomes constant because the rate of formation of $^{239}_{93}Np$ is equal to the rate of decay.
(vi)	Rate of decay = λN $= \left(\frac{ln2}{2.04\times10^5}\right)N$ $\left(\frac{ln2}{2.04\times10^5}\right)N = 1.80\times10^7$ N = 5.3 x 10^{12}
(vii)	Students are expected to be able to deduce that the number of $^{239}_{93}Np$ increases from zero until it reaches a steady value of 5.3 x 10^{12}
(viii)	Rate of production of $^{239}_{94}Pu$ = rate of decay of $^{239}_{93}Np = 1.80\ \times\ 10^7 s^{-1}$
(ix)	Students are expected to deduce that the number of $^{239}_{94}Pu$ nuclei at any instant is equal to X minus Y.
(x)	Maximum rate of decay of $^{239}_{94}Pu \approx \frac{\ln 2}{7.58\times10^{11}}\left((10.8-5.3)\times10^{12}\right)$ = 5 s^{-1} Maximum number of nuclei decayed after 6 x 10^5s = 3 x 10^6 This number is insignificant compared to the number of $^{239}_{94}Pu$ present which is of the order of 10^{12} nuclei, hence insignificant effect on the shape of Z. Or fraction of $^{239}_{94}Pu$ nuclei remaining after t = 6 x 10^5 sec =

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			$e^{\frac{-ln2}{7.58\times10^{11}}\times6\times10^{5}}$ = 0.999,999. Hence the $^{239}_{94}Pu$ nuclei are approximately stable within the time frame of 6 x 10^5 seconds (since this duration is much smaller than the half life of $^{239}_{94}Pu$), hence no significant effect on the shape of Z.	
		(xi)	k.e. of $\alpha = \frac{235}{239} \times 5.16 \times 10^6 \times 1.6 \times 10^{-19} = 8.118 \times 10^{-13}$ velocity of $\alpha = \sqrt{\frac{2\times8.118\times10^{-13}}{4u}}$ = 1.56 x 10^7 ms^{-1}	

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Write in dark blue or black pen on both sides of the paper.
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Do not use staples, paper clips, highlighters, glue or correction fluid.
Answers **all** questions.

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1 When an object falls in air, it experiences a drag force which opposes the motion of the object. Larger objects experience greater drag forces. In this experiment, you will investigate how the terminal velocity of a paper cone falling in air depends on the diameter of the cone.

(a) Cut a sector out of a piece of filter paper as shown in Fig. 1.1.

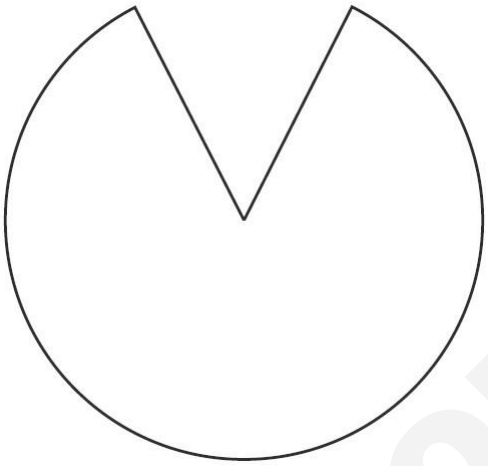

Fig 1.1

(b) (i) Tape the straight edges of the paper together to produce a cone, as shown in Fig. 1.2.

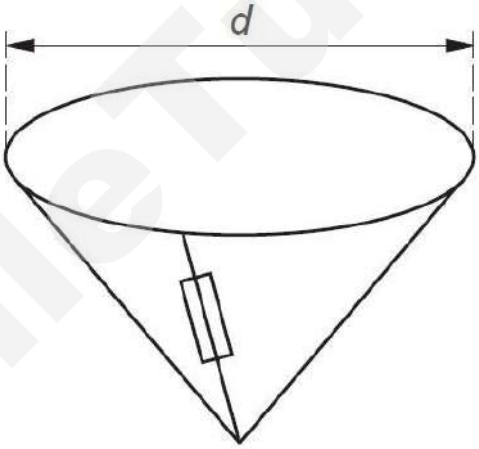

Fig. 1.2

(ii) Measure and record the diameter *d* of the cone.

d = 11.0 cm .....[1]

[1m: d.p. + unit]

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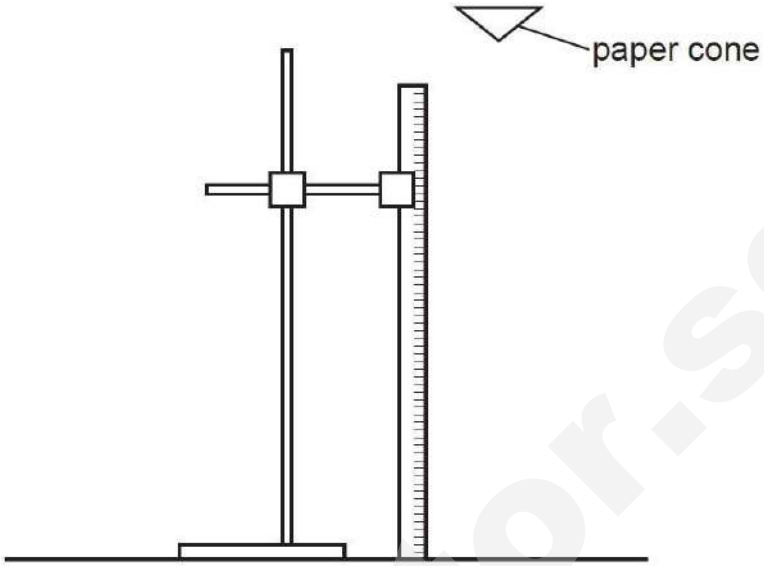
(c) (i) Mount a metre rule vertically using a stand, boss and clamp.

(ii) Release the cone from a short distance above the top of the metre rule, as shown in Fig. 2.3.



Make and record measurements to determine the time *t* for the cone to fall through a distance *h* from the top of the metre rule.

t_1 = 1.0 s
t_2 = 0.9 s
t_{ave} = 1.0 s

[1m: repeat readings]
[1m: d.p. + unit + 0.700 m ≤ h ≤ 1.000m]

h = 1.000 m

t = 1.0 s
[2]

(d) Estimate the percentage uncertainty in *t*, showing your working.

0.5/1.0 x 100% = 50 %

[1m: Δt 0.3 to 0.7 s]
[1m: 2 s.f. + unit]

percentage uncertainty in *t* = 50 % [2]

(e) Calculate the terminal velocity *v* of the cone.

$$v = \frac{h}{t}$$
$$= \frac{1.000}{1.0}$$
$$= 1.0\ ms^{-1}$$

[1m: correct calculation]
[1m: s.f. + unit]

v = 1.0 ms^{-1} [2]

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(f) (i) Remove the tape from the paper and cut away a larger sector as shown in Fig. 1.4.

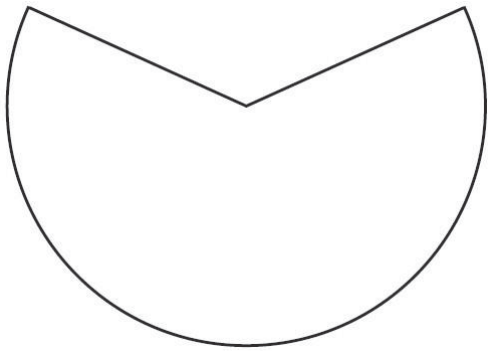

Fig. 1.4

(ii) Repeat **(b)**, **(c)(ii)** and **(e)**, recording your results below.

t_1 = 0.6 s
t_2 = 0.7 s
t_{ave} = 0.7 s

$$v = \frac{h}{t}$$
$$= \frac{1.000}{0.7}$$
$$= 1.4\ ms^{-1}$$

d = 9.0 cm .....
h = 1.000 m .....
t = 0.7 s .....
v = 1.4 ms^{-1} .....
[2]

[1m: correct calculation]
[1m: s.f./d.p. + unit + repeat reading]

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(g) It is suggested that *v* is inversely proportional to *d*. Do the results of your experiment support this suggestion? State and explain your reasoning clearly.

If the relationship is valid, then
$v = kd^{-1}$

Thus, $k = vd$ [1m: correct relationship stated/used]

[1m: calculation of the proportionality constants]

$k_1 = (1.0)(11.0) = 11\ m^2\ s^{-1}$
$k_2 = (1.4)(9.0) = 13\ m^2\ s^{-1}$ [1m: percentage uncertainty.]

[1m: test against a stated criterion.]

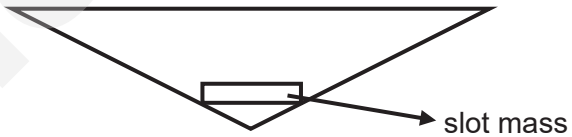
$k_{ave} = (11 + 13)/2 = 12\ m^2\ s^{-1}$
$\Delta k = 2\ m^2\ s^{-1}$

Percentage uncertainty = $\Delta k / k_{ave}$ x 100% = 2/12 x 100% = 17% (2 s.f.)

Since the percentage error is 17%, which is less than 20%. Thus the suggested relationship is valid within the experimental error.

[4]

(h) In parachute making, it is also necessary to take into account the mass of the parachutist. Suggest changes to the paper cone experiment described above to study how a mass can affect the terminal velocity of the paper cone.



small slot mass can be added to the inverted paper cone. By varying the number of slot mass, the relationship between the attached mass and terminal velocity can be determine. It should be noted that the diameter of the cone should be kept constant.

[2]

[1m: workable experiment]
[1m: diameter should be kept constant.]

[Total: 15 marks]

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2

This investigation considers the amount of charge flowing through a resistor.

(a) (i) Set up the circuit shown in Fig. 2.1, taking care to connect component Y the right way round.

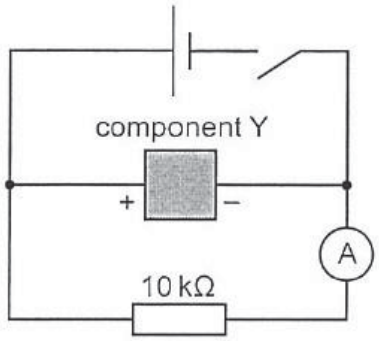


Fig. 2.1

(ii) Close the switch and wait about 10 s . Record the reading I on the ammeter.

[1m: value + unit]

I = 147.4 μA ..... [1]

(b) When the switch is opened, the current in the resistor gradually decreases to zero.

(i) Open the switch and start the stopwatch.

(ii) While the current is decreasing, record at least five readings of I and the time elapsed t up to a value of t = 50 s. You may need several attempts before you have a satisfactory set of results. You will need this set of readings to plot a graph in 2(c).

t /s	I_1 /μA	I_2 /μA	I_{ave} /μA
10	75.1	78.5	76.8
20	44.9	46.0	45.5
30	27.4	28.0	27.7
40	16.7	17.1	16.9
50	10.2	10.7	10.5

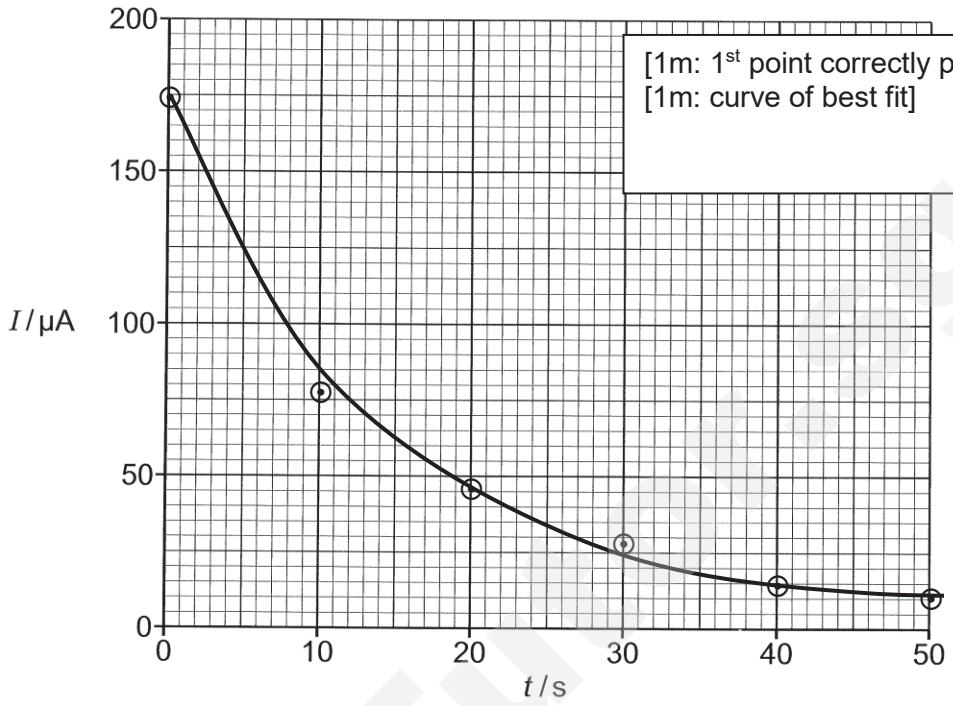
[1m: 5 or 6 readings showing correct trend]
[1m: I to 0.1 μA and t to 0.01 s, 0.1 s or 1 s]

[2]

(iii) State two problems that arose in taking the readings.

1 .....
1. decay is too quick.
2. difficulties in reading two instruments simultaneously.
3. when taking repeated set of readings, the initial reading of the current varies.
.....
2 .....
.....
.....
.

(c) Plot your values from **(b)(ii)** on Fig. 2.2. The graph obtained should be a curve.



[1m: 1st point correctly plotted]
[1m: curve of best fit]

Fig. 2.2

[2]

(d) The area under the graph represents the charge Q that has flowed through the resistor during the 50 s. Estimate this charge.

[1m: estimate of charge from area under the graph + unit]

Q = 2.78 x 10^{-3} C ..... [1]

[Total: 8 marks]

area under graph

$= \frac{1}{2}(175\times10^{-6}+85\times10^{-6})10 + \frac{1}{2}(85\times10^{-6}+25\times10^{-6})20 + \frac{1}{2}(25\times10^{-6}+12.5\times10^{-6})20$

= 2.78 x 10^{-3} C

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3 In this experiment, you will investigate the motion of a system of masses.

(a) Set up the apparatus as shown in Fig. 1.1, with the shorter length of string above the central loop and the longer length of string below the central loop.
Place four slotted masses in the bottom loop and four slotted masses in the central loop.

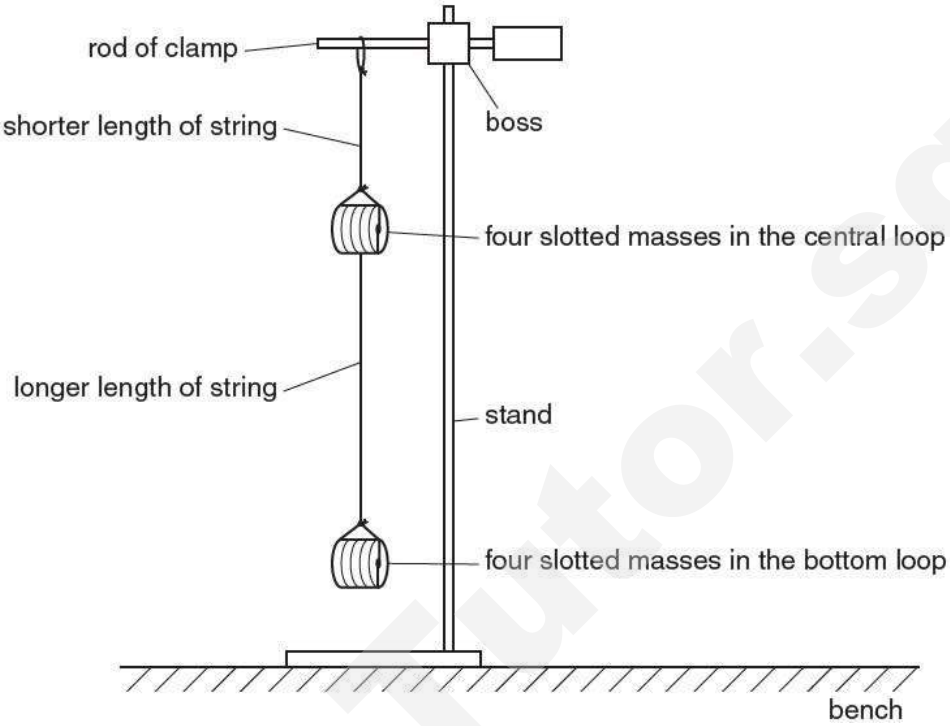

Fig 3.1

(b) Move the slotted masses in the bottom loop to the left.
Release the slotted masses and watch the movement.
The slotted masses will move to the right and then to the left again, completing a swing as shown in Fig. 3.2.

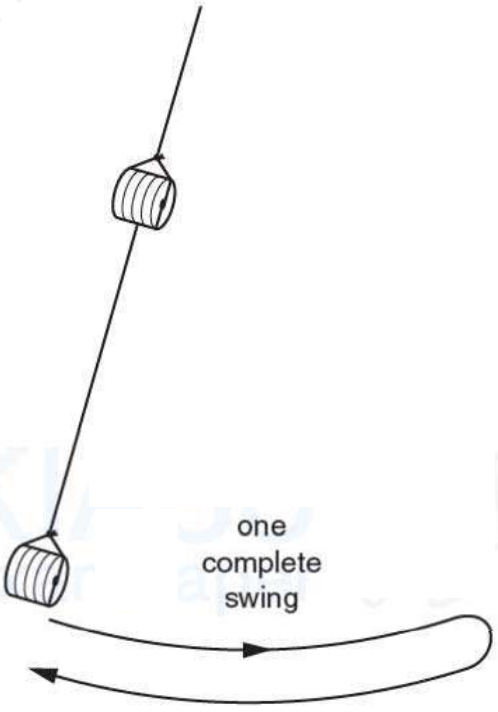

Fig 3.2

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(c) Make and record measurements so that the period T of these oscillations may be determined.

t_1 = 11.9 s
t_2 = 12.0 s
t_{ave} = 12.0 s

N = 10
T = 1.20 s

[1m: repeated readings]
[1m: correct calculation + unit. Do not allow total time taken.]

T = 1.20 s [2]

(d) Change the number of slotted masses in each loop. Use **all** the eight slotted masses.

(i) Count and record the number *B* of slotted masses in the bottom loop.

B = 5

(ii) Count and record the number *C* of slotted masses in the central loop.

C = 3

(iii) Repeat **(b)**.

t_1 = 12.3 s
t_2 = 12.2 s
t_{ave} = 12.3 s

N = 10
T = 1.23 s

T = 1.23 s

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(e) Repeat **(d)** until you have six sets of values of *B*, *C* and *T*. Include your results from **(c)** and **(d)**.

For each set of values, use all eight slotted masses.

N	B	C	t_1 /s	t_2 /s	t_{ave} /s	T /s	T^2 /s^2	C/B	T^2/B /s^2
10	6	2	12.4	12.5	12.5	1.25	1.55	0.33	0.258
10	5	3	12.3	12.2	12.3	1.23	1.50	0.60	0.300
10	4	4	11.9	12.0	12.0	1.20	1.43	1.0	0.357
10	3	5	11.4	11.4	11.4	1.14	1.30	1.7	0.433
10	2	6	11.1	11.0	11.1	1.10	1.22	3.0	0.611
10	1	7	10.6	10.5	10.6	1.06	1.11	7.0	1.11

2m – 6 data points w/o help
– 1m if 4 data points w/o help
– 0m if 3 or less data points w/o help
– deduct 1m if help required
– deduct 2m if help required extensively
– deduct 1m if wrong trend
– min is zero mark

1m – total t more than 10 s

1m – column headings

1m – raw data correct precision. 1 or 2 d.p. for t.

1m – calculated values to same s.f. as raw data or 1 more

1m – all data calculated correctly

[7]

(f) The quantities *T*, *B* and *C* are related by the equation

$$\frac{T^2}{B} = \frac{FC}{B} + G$$

where *F* and *G* are constants.

By plotting a suitable graph, determine the values of *F* and *G.*

By plotting a graph of **T^2/B against C/B**, **a straight line should be obtained** with F as the gradient and G the y-intercept. **[1 - linearize eqn]**

Using (6.40, 1.030) and (0.80 ,0.330)

From the graph, gradient = (1.030 – 0.330) / (6.40 – 0.80) **[1 - gradient]**
= 0.700 / 5.60
= 0.125

Thus F = 0.125 s^2

Using the equation form y = mx + c, gradient = 0.125, **(6.40, 1.030)**

1.030 = 0.125 (6.40) + c **[1 – y-intercept]**
c = 1.030 – 0.8 = 0.2

Thus, G = 0.2 s^2 **[1 – F and G with correct units]**

[4]

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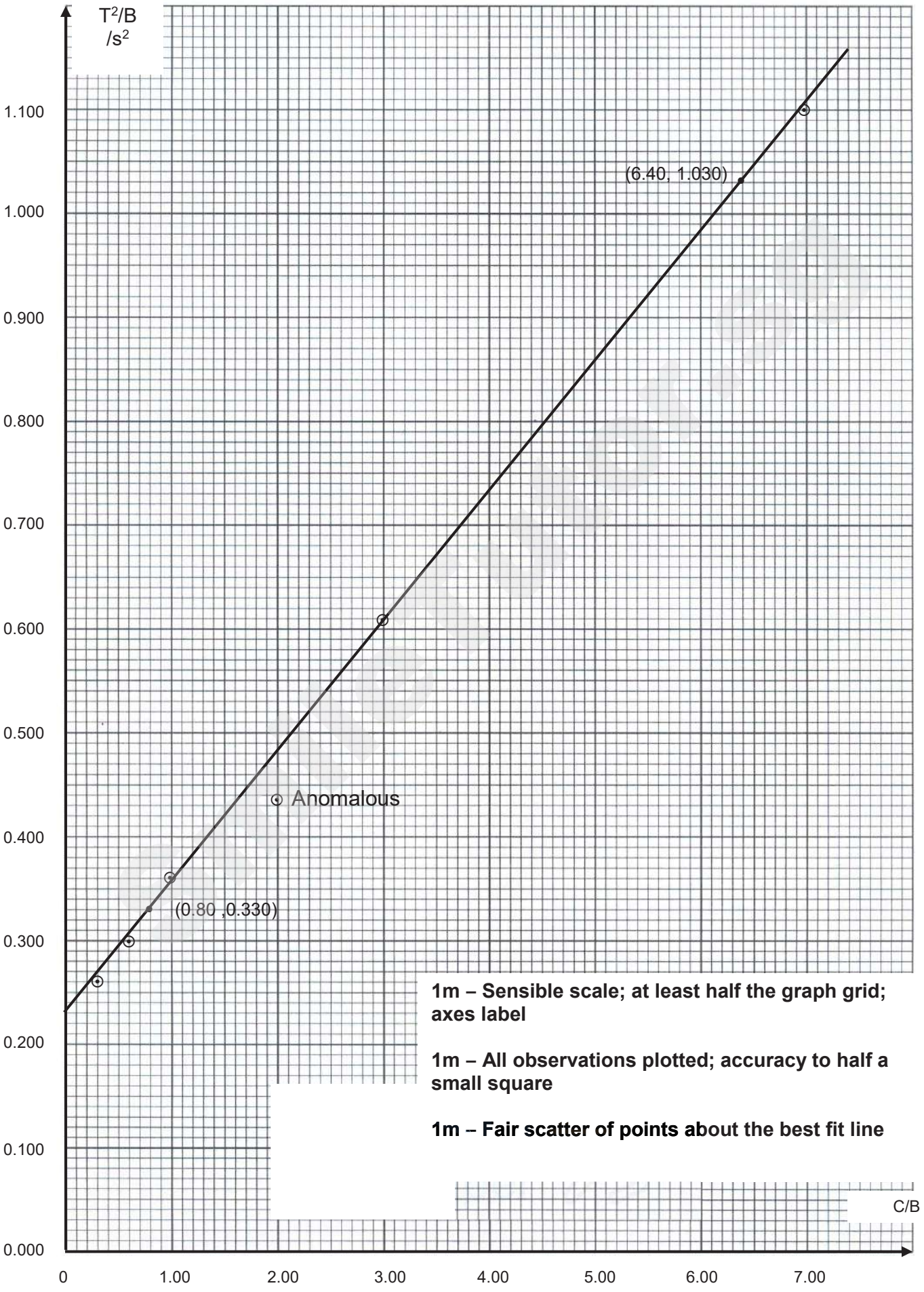

1m – Sensible scale; at least half the graph grid; axes label

1m – All observations plotted; accuracy to half a small square

1m – Fair scatter of points about the best fit line

[3]

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(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

There is no anomalous data as all points lie close to the best fit line.
OR
There is no anomalous data as all points lie around the best fit line.
OR
There is/are anomalous data because 1 *(or 2)* points *is/are* very much further from the best fit line compared to rest of the points. **[1]**

(h) **(i)** State two significant error or limitation of the procedure in the experiment.

- The loop that was used to loop into the rod was much bigger than the diameter of the rod. When the pendulum swings, the loop slips and slides along with the motion. Friction may affects the time taken of the period.
- As the loop is of fixed length, the length from pivot to mass may change when more slot masses were added to the loop. To accommodate more slot mass, the shape of the loop has to adjust horizontally instead. Thus shortening the length from pivot to center of mass. (see diagram below)
-

[2]

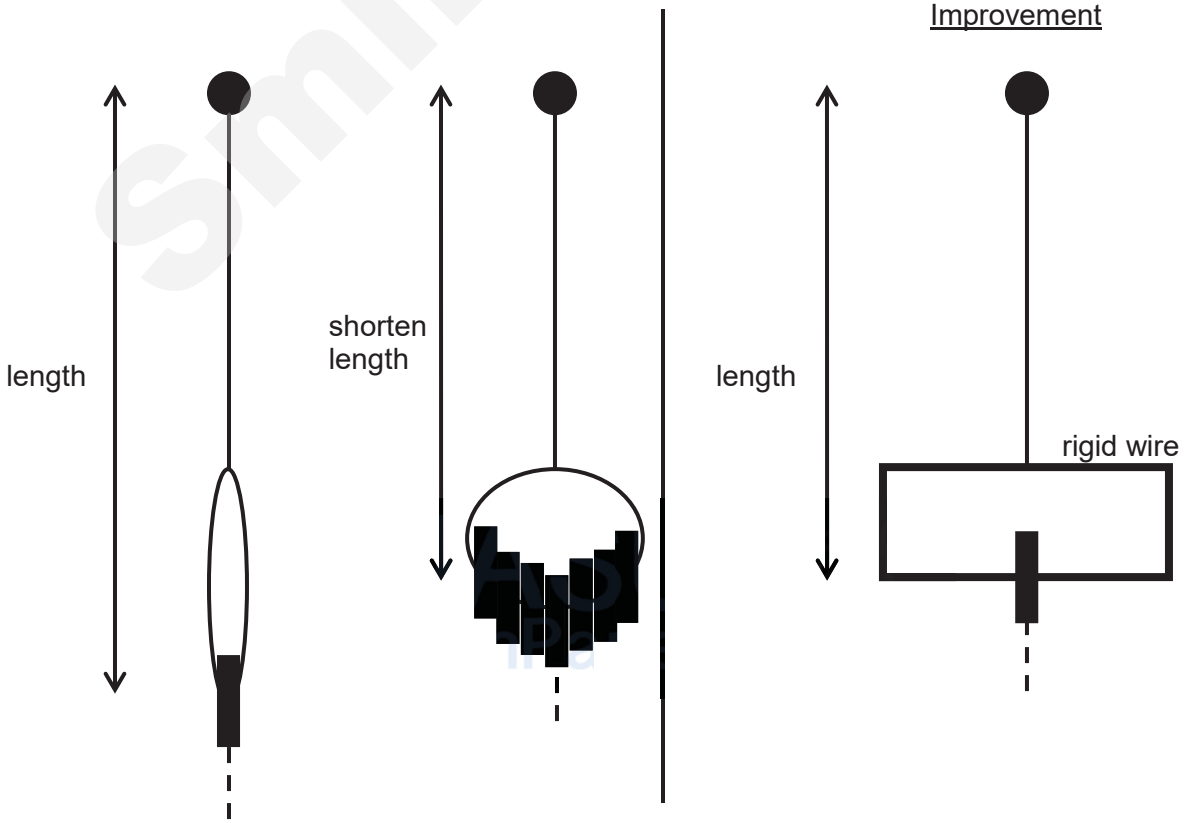
(ii) Suggest an improvement that could be made to the experiment to address the error/limitation in **h**(**i**). You may suggest the use of other apparatus or different procedures.

- Tie the pendulum directly onto the rod instead of looping around the rod.

- Use rigid wire and shape it to accommodate all 8 pieces before the start of experiment. (see diagram)

[1]

[Total: 20]



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4 A hot air balloon is tied to the ground using a rope. As the wind blows with speed *v*, the rope makes an angle *θ* to the horizontal, as shown in Fig 4.1.

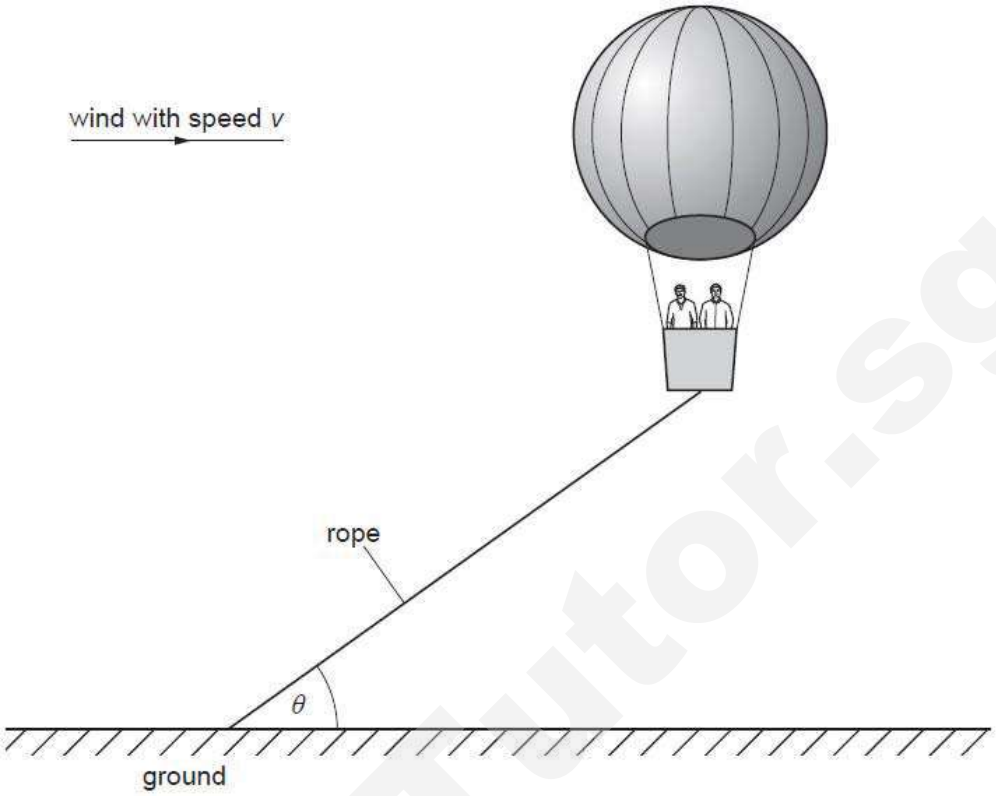

Fig 4.1

It is suggested that

$$\tan\theta = \frac{k}{v^2}$$

where k is a constant.

To model the hot air balloon in the laboratory, a balloon filled with helium is used. You may also use any of the other equipment usually found in a physics laboratory.

Design a laboratory experiment using a small helium-filled balloon to test the relationship between *θ* and *v,* and to determine a value for k.

You should draw a diagram, showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(b) how the speed of the wind and angle are measured,
(c) the control of variables,
(d) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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…… [12]

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Defining the problem (3 marks)

P1 v is the independent variable and θ is the dependent variable or vary v and measure θ. [1]

P2 Keep the (shape and) size/volume/surface area/mass of balloon/helium constant [1]
Do not credit 'same balloon'.

P3 Keep the temperature (air/helium/balloon) constant. [1]

Methods of data collection (4 marks)

M1 Labelled diagram of apparatus: balloon, string fixed and method of producing wind.
Method of producing wind to be approximately horizontal to balloon. [1]

M2 Method to change wind speed, e.g. change setting, variable power supply/resistor/change distance from fan. [1]

M3 Method to measure wind speed, e.g. wind speed indicator/detector, anemometer [1]

M4 Method to measure angle – use protractor or rule for measurements for trigonometry methods.
This must be shown correctly on diagram or explained in text. [1]

Method of analysis (2 marks)

A1 Plot a graph of tan θ against $1/v^2$ to obtain a straight line to validate equation. [1]

A2 Relate gradient to k. [1]

Safety considerations (1 mark)

S1 Avoid the moving blades of the fan (safety screen, switch off when changing experiment); goggles to avoid air stream into eye. [1]

Additional detail (2 marks)

Relevant points might include [2]

D1 Large wind speed to produce measurable deflection/large cross-sectional area of balloon.

D2 Measuring air speed at point where balloon is positioned.

D3 Adjust height of fan so that air flow is horizontally aligned to the balloon.

D4 Reason for adding mass to increase stability/deflection.

D5 Wait for the balloon to become stable.

D6. Preliminary result

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Q1

1 Retort Stand with boss and clamp
2 Metre rule
3 Circular piece of filter paper
4 Scissors
5 Stopwatch
6 Sellotape

Q2

1 1.5 V dry cell in holder
2 Component Y
3 10 kΩ resistor
4 Six connecting leads
5 Stopwatch
6 Digital Multimeter
7 Switch

Q3

1 Retort Stand with boss and clamp
2 Metre rule
3 String
4 Eight 10 g slotted mass
5 Stopwatch

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Apparatus List

Q1

1 Retort Stand with boss and clamp

2 Metre rule

3 Circular piece of filter paper

4 Scissors

5 Stopwatch

6 Sellotape

Q2

1 1.5 V dry cell in a holder.

2 1000 μF capacitor. The capacitor should be covered in masking tape so that candidates cannot see any details printed on it. It should be labelled "**component Y**" and the polarity of the connections should be indicated with a "**+**" and a "**–**".

3 10 kΩ resistor.

4 Six connecting leads.

5 Stopwatch reading to 0.1 s or better.

6 Digital multimeter set on the 200 μA range.

7 Switch.

Q3

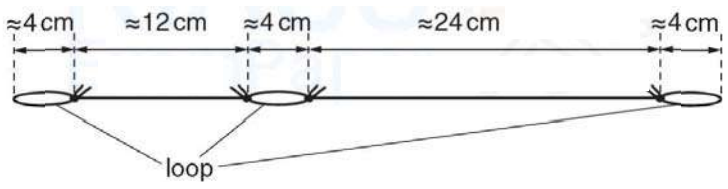
1 Retort Stand with boss and clamp

2 Metre rule

3 String (see diagram)

4 Eight 10 g slotted mass

5 Stopwatch



Each loop should be big enough to accommodate the eight slotted masses.

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Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/01**
Higher 2

Paper 1 Multiple Choice

22 September 2017

1 hour

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **18** printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\varphi = -\frac{GM}{r}$
temperature	$T\ /\ \mathrm{K} = T\ /\ ^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 When a constant braking force is exerted on a train travelling at speed v, the distance s moved by the train in coming to a stop is given by the expression

$$s = kv^2$$

where k is a constant.

When v is measured in metres per second and s is measured in metres, the constant has a value of k_1.

What is the value of the constant when the speed is measured in kilometres per hour, and the distance is measured in kilometres?

A $7.72 \times 10^{-5}\ k_1$

B $2.78 \times 10^{-4}\ k_1$

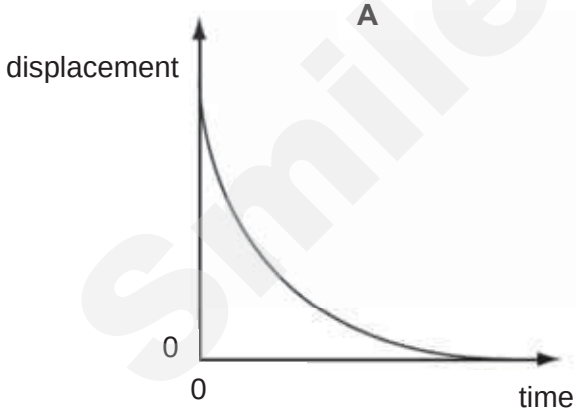
C $3.60 \times 10^{-3}\ k_1$

D $1.30 \times 10^{-2}\ k_1$

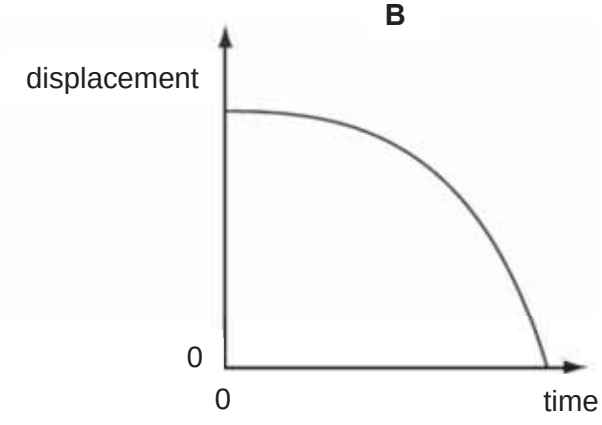
2 An object is released from rest and falls vertically. Its initial acceleration decreases until it eventually reaches terminal velocity.

Which graph best represents how the displacement of the object varies with time?

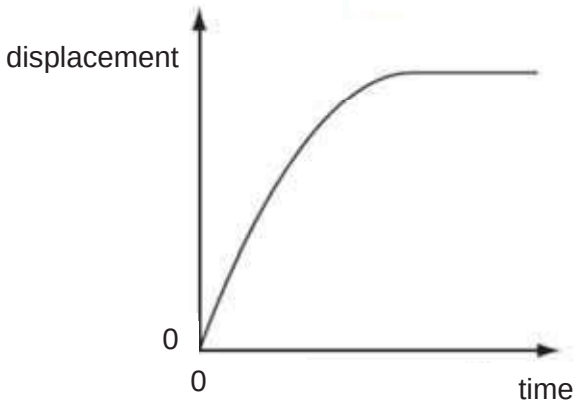
A



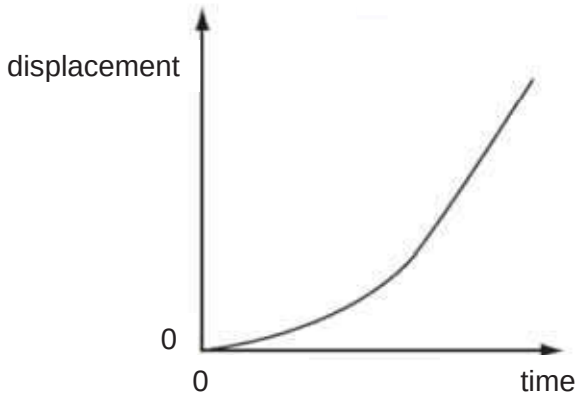
B



C



D



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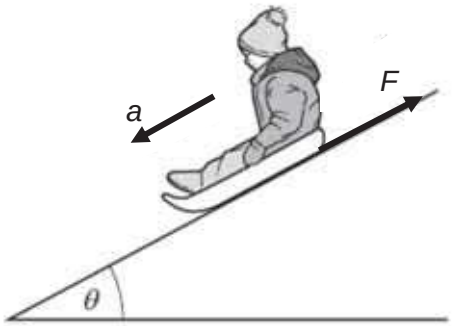
3 A child on a sledge slides down a slope with acceleration a. The slope is inclined at an angle θ above the horizontal.



The mass of the child is m and the mass of the sledge is M. The acceleration of free fall is g. Ignore the effects of air resistance.

What is the frictional force F?

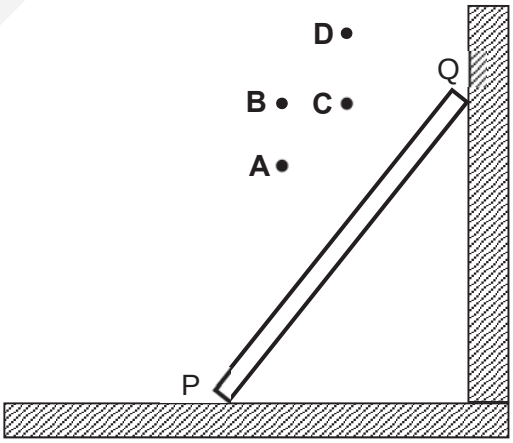
A $m(g\sin\theta - a)$

B $m(g\cos\theta + a)$

C $(m+M)(g\sin\theta - a)$

D $(m+M)(g\cos\theta - a)$

4 The diagram shows a non-uniform plank PQ resting against a wall. The resultant forces at P and Q are F_P and F_Q respectively.



If the plank is in equilibrium, which point must F_P and F_Q act through?

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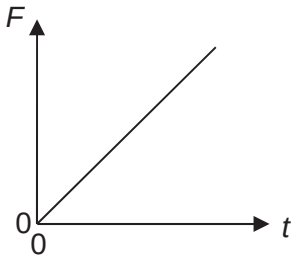
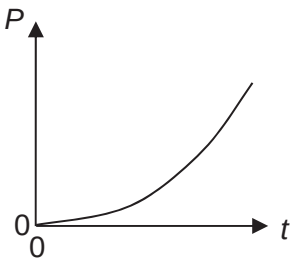
5 The graph shows the variation with time t of the driving force F exerted by the engine on a vehicle.

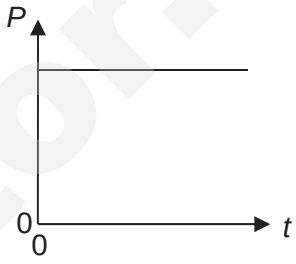


Which graph shows the variation with time t of the power P delivered by the engine?

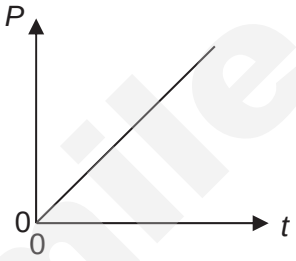
A



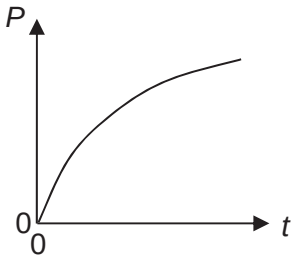
B



C



D



6 Astronomical observations show that the length of the day increased by approximately 6×10^{-3} s from the years 1870 to 1900.

What is the corresponding percentage change in the Earth's angular velocity?

A -1.9×10^{-8} %

B -6.9×10^{-6} %

C 1.9×10^{-8} %

D 6.9×10^{-6} %

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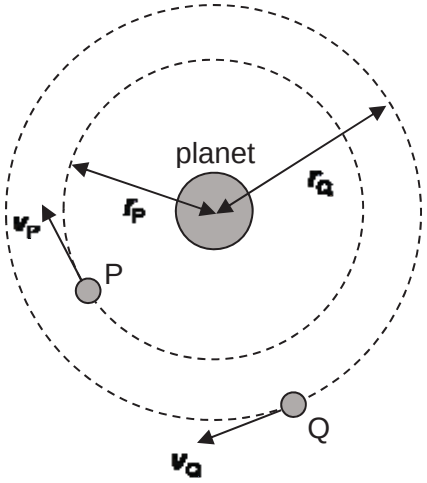
7 Two moons P and Q have circular orbits about a planet as shown below.



(not to scale)

Moon P has an orbital radius r_P of 1.4×10^{8} m and linear speed v_P. Moon Q has an orbital radius r_Q of 2.3×10^{10} m and linear speed v_Q.

What is the ratio $\frac{v_P}{v_Q}$?

A 6.1×10^{-3}

B 7.8×10^{-2}

C 13

D 160

8 A satellite of mass 80 kg moves from a point where its gravitational potential energy due to Earth is −4800 MJ, to another point where its gravitational potential energy is −1600 MJ.

In which direction does the satellite move and what is its change in gravitational potential?

A closer to the Earth and a loss of 40 MJ kg^{-1} of potential.

B closer to the Earth and a loss of 3200 MJ kg^{-1} of potential.

C further from the Earth and a gain of 40 MJ kg^{-1} of potential.

D further from the Earth and a gain of 3200 MJ kg^{-1} of potential.

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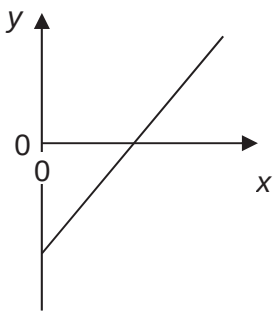
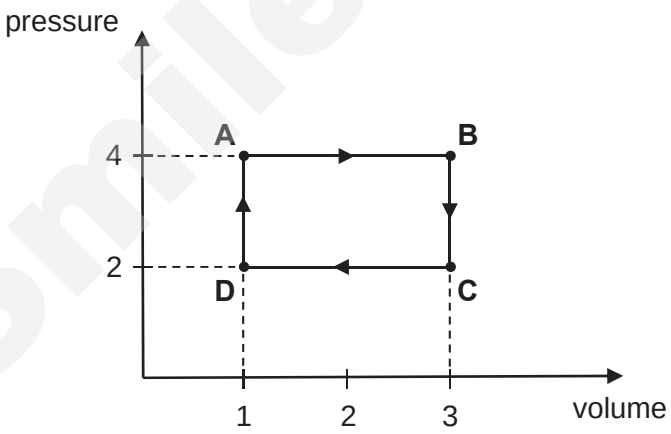
9 The graph shows the relationship between the volume and temperature of a fixed mass of an ideal gas at constant pressure.



What is the quantity and appropriate unit on each axis for this graph?

	y-axis	x-axis
A	temperature / K	volume / m^3
B	temperature / °C	volume / m^3
C	volume / m^3	temperature / K
D	volume / m^3	temperature / °C

10 A fixed mass of ideal gas undergoes a cycle of changes as shown.



At which point on the graph do the gas molecules have the lowest root-mean-square speed?

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11 An ideal gas exerts a pressure of 60 Pa when its temperature is 400 K and the number of molecules present per unit volume is N. Another sample of the same gas exerts a pressure of 30 Pa when its temperature is 300 K.

How many molecules are present per unit volume of this second sample?

A $\frac{3N}{2}$

B $\frac{4N}{3}$

C $\frac{3N}{4}$

D $\frac{2N}{3}$

12 Which of the following statements about a simple harmonic oscillator is correct?

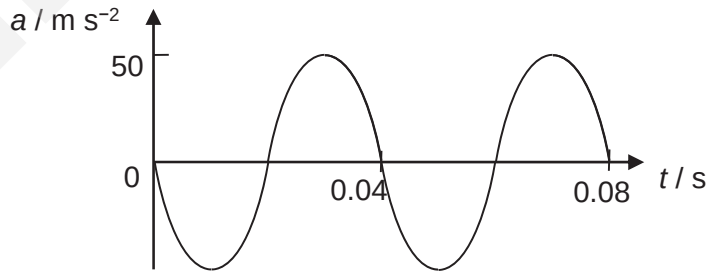
A The kinetic energy of the oscillator is proportional to the frequency of its motion.

B The potential energy of the oscillator is minimum when the oscillator is momentarily at rest.

C The kinetic energy of the oscillator is zero when the oscillator is at the equilibrium position.

D When the kinetic energy of the oscillator is equal to its potential energy, the oscillator is neither at the rest position nor at the maximum displacement positions.

13 A body performs simple harmonic motion with period T. The graph shows the variation with time t of its acceleration a.



What is the ratio of the body's displacement to its amplitude at time $t = \frac{5T}{8}$?

A −0.71

B 0.71

C −0.87

D 0.87

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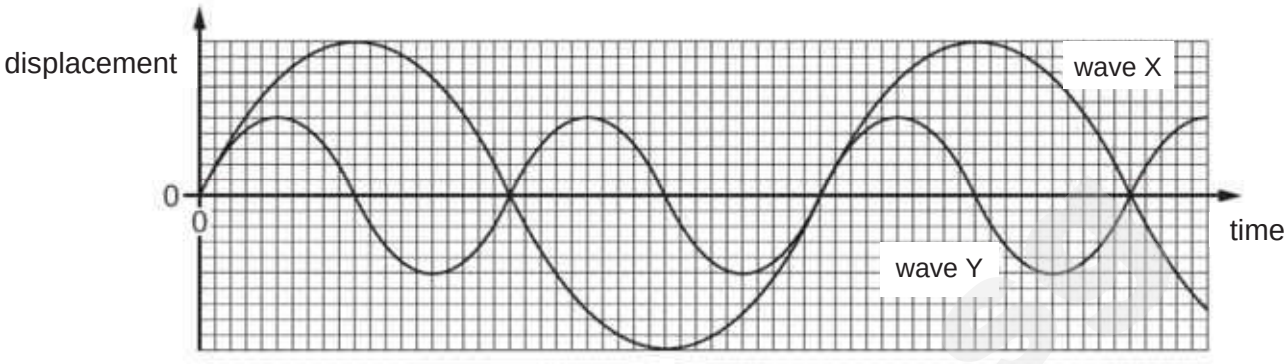
14 The graph shows the variation with time of the displacement of two separate waves X and Y.



Wave X has frequency *f* and amplitude *A*.

What is the frequency and amplitude of wave Y?

	frequency	amplitude
A	2*f*	2*A*
B	2*f*	0.5*A*
C	0.5*f*	2*A*
D	0.5*f*	0.5*A*

15 A wave of frequency 20 Hz travels at 32 m s^{-1} through a medium.

What is the phase difference between two points 2.8 m apart?

A There is no phase difference.

B They are out of phase by half a cycle.

C They are out of phase by two thirds of a cycle.

D They are out of phase by three quarters of a cycle.

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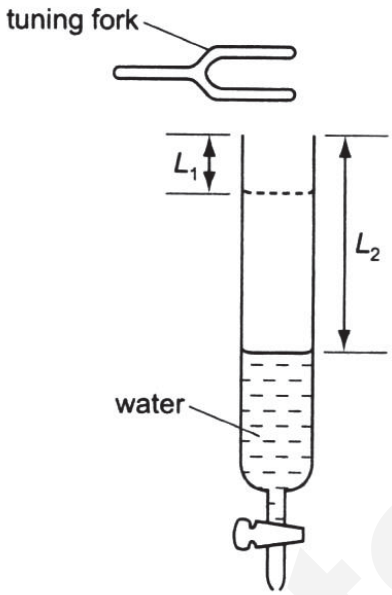
16 A tuning fork is made to vibrate above a burette filled with water. The water is allowed to run out of the tube.



A loud sound is heard when the length of the air column is 0.18 m and again when the length is 0.45 m.

What is the wavelength of the sound in the tube?

A 0.27 m

B 0.36 m

C 0.54 m

D 1.1 m

17 Two coherent waves, of intensities I and $4I$, meet in anti-phase at a point.

What is the resultant intensity at that point?

A 0

B I

C $3I$

D $5I$

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18 Which of the following statements about an electric field is **incorrect**?

A The electric field strength is zero at all points where the electric potential is zero.

B The electric field strength at a point is a measure of the electric potential gradient at that point.

C The electric field strength due to a point charge varies as $\frac{1}{r^2}$ where r is the distance from the charge.

D The electric field strength at a point is a measure of the force exerted on a unit positive charge at that point.

19 A proton and an alpha particle are accelerated from rest through a potential difference of V.

If the final momentum of the proton is p, what is the final momentum of the alpha particle?

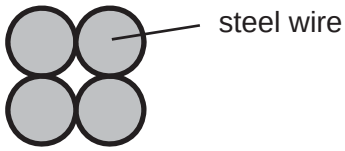
A $\sqrt{2}p$

B $2p$

C $2\sqrt{2}p$

D $4p$

20 An electrical supply cable consists of four identical steel wires arranged next to one another. Each wire has a cross-sectional area of 50 mm^2 and a resistivity of $9.0 \times 10^{-8}\ \Omega$ m. The cross-section of the cable is as shown.



What is the resistance of 100 m length of the cable?

A $4.5 \times 10^{-8}\ \Omega$

B $7.2 \times 10^{-7}\ \Omega$

C $0.045\ \Omega$

D $0.72\ \Omega$

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21 A uniform copper rod of cross-sectional area 8.0×10^{-6} m^2 has 8.5×10^{28} conduction electrons per cubic metre. A current flows through the rod when a potential difference is applied across it.

Given that the drift velocity of electrons in the rod is 2.3×10^{-5} m s^{-1}, what is the current in the rod?

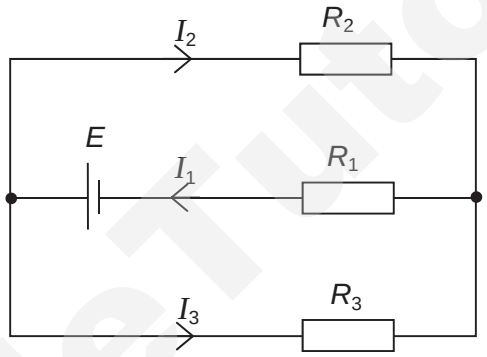
A 0.25 A

B 0.40 A

C 2.5 A

D 4.0 A

22 A cell of e.m.f. E and negligible internal resistance is connected in a circuit causing currents I_1, I_2 and I_3 in the three resistors of resistance R_1, R_2 and R_3 respectively.



Which equation relating to this circuit is correct?

A $E + I_3R_3 = I_1R_1$

B $E - I_2R_2 = I_1R_1$

C $E + I_1R_1 = \dfrac{I_1R_2R_3}{(R_2 + R_3)}$

D $E - I_1R_1 = I_2R_2 + I_3R_3$

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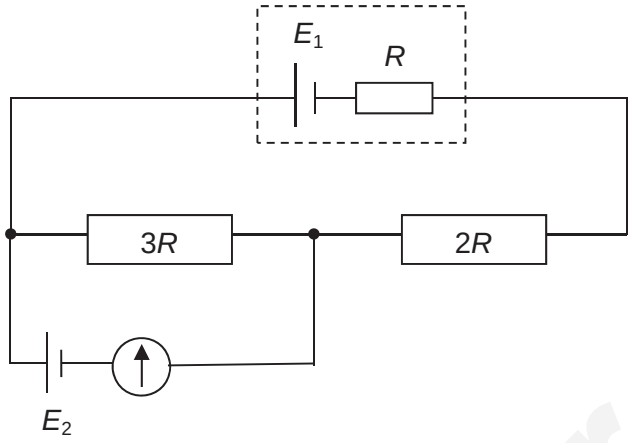
23 Two cells of e.m.f. E_1 and E_2 have internal resistances R and zero respectively. The cells are connected to resistors of resistances $3R$ and $2R$, as shown below.



If the galvanometer shows no deflection, what is the ratio $\frac{E_1}{E_2}$?

A 0.60

B 1.0

C 1.7

D 2.0

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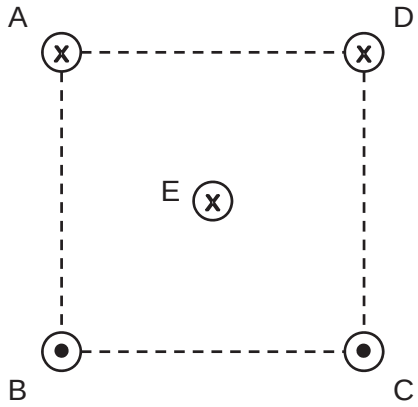
24 Four parallel conductors A, B, C and D carrying equal currents, pass vertically through the four corners of a square. In conductors A and D, the current is flowing into the page, and in conductors B and C, current is flowing out of the page.



Which of the following **incorrectly** describes the resultant force on conductor E, with current flowing into the page, at the centre of the square?

A The resultant force due to wires B and D points towards line AD, perpendicular to AD.

B The resultant force due to wires B and C points towards line AD, perpendicular to AD.

C The resultant force due to wires A and D points towards line AD, perpendicular to AD.

D The resultant force due to wires A, B, C and D points towards line AD, perpendicular to AD.

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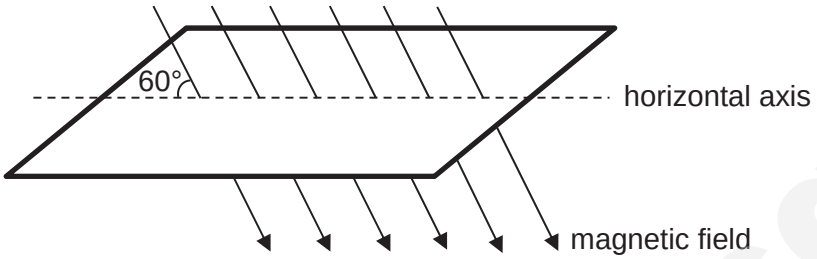
25 A magnetic field of flux density 4.0×10^{-4} T passes through a coil of wire of 50 turns and an area of 30 cm^2. The field makes an angle of 60° with the horizontal plane of the coil.



What is the e.m.f. induced in the coil when it is turned over once about its horizontal axis in a time of 0.60 s?

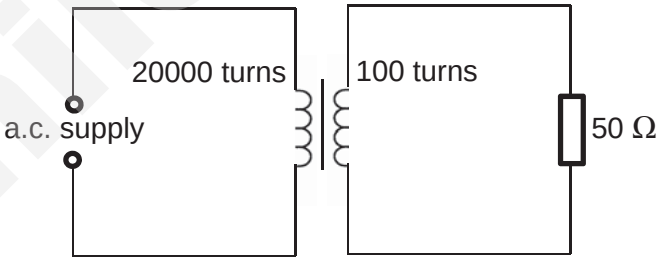
A 5.0×10^{-5} V

B 8.7×10^{-5} V

C 1.0×10^{-4} V

D 1.7×10^{-4} V

26 The primary of a non-ideal transformer has 20000 turns and is connected to an a.c. supply. The secondary has 100 turns and is connected to a resistor of resistance 50 Ω. The r.m.s. secondary voltage is 210 V. The transformer is 60% efficient.



What is the r.m.s. primary current?

A 0.013 A

B 0.021 A

C 0.035 A

D 4.2 A

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27 When electrons with velocity *v* travel through a vacuum and are incident on a thin carbon film, they produce a pattern of concentric circles on the fluorescent screen.

What causes the pattern and how would the pattern change when the velocity *v* is decreased?

	cause	change to pattern
A	refraction	diameters of circles decrease
B	refraction	diameters of circles increase
C	diffraction	diameters of circles decrease
D	diffraction	diameters of circles increase

28 The line spectrum of hydrogen includes no X-ray frequencies.

The reason for this is

A the ionisation energy is too low.

B the work function energy is too high.

C there is only one electron in a hydrogen atom.

D there are too few electronic energy levels in the hydrogen atom.

29 Nucleus P decays in two stages to produce nucleus Q.

Which decay sequence will result in the highest number of neutrons in nucleus Q?

A a β-particle followed by a γ-ray

B an α-particle followed by a γ-ray

C an α-particle followed by a β-particle

D a β-particle followed by another β-particle

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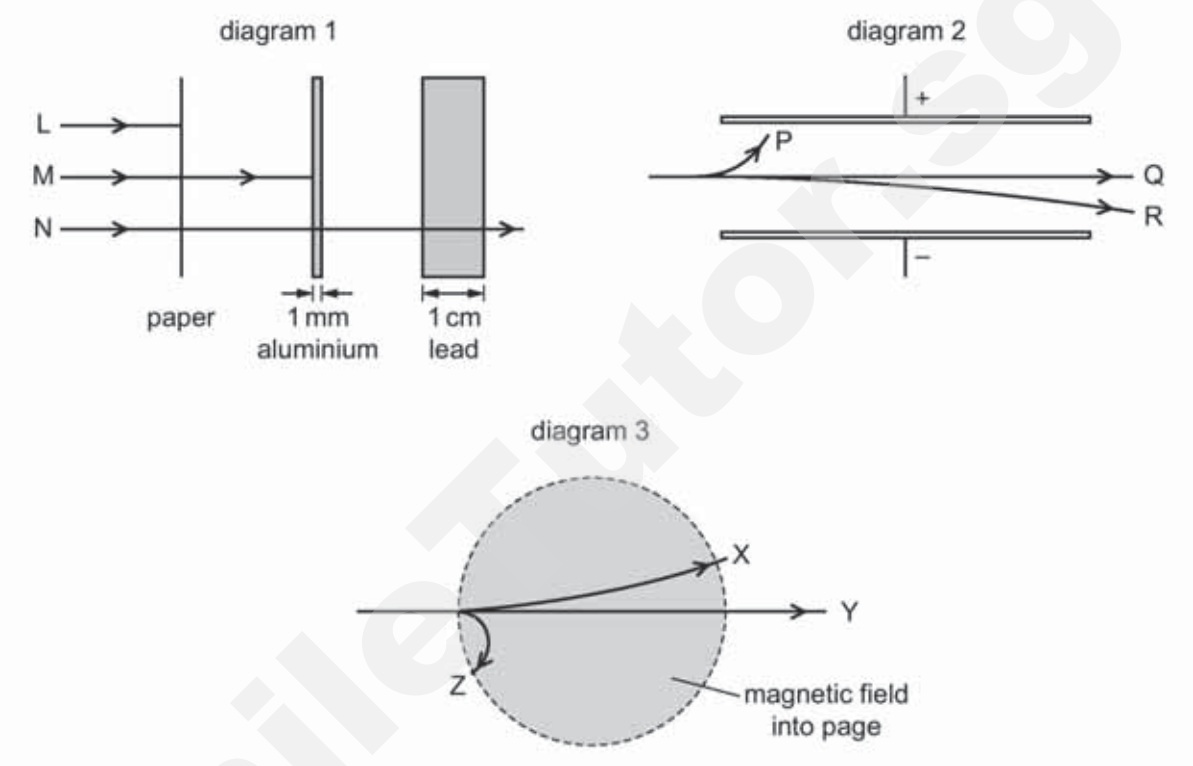
30 Alpha, beta and gamma radiations

1 are absorbed to different extents in solids,

2 behave differently in an electric field,

3 behave differently in a magnetic field.

The diagrams illustrate these behaviours.



Which three labels on these diagrams refer to the same kind of radiation?

A L, P, X **B** M, P, Z **C** M, R, X **D** N, Q, X

End of paper

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Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/02**
Higher 2

Paper 2 Structured Questions

15 September 2017

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 10
2	/ 9
3	/ 12
4	/ 11
5	/ 10
6	/ 9
7	/ 19
Total	/ 80

This document consists of **22** printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\varphi = -\frac{GM}{r}$
temperature	$T\,/\,\mathrm{K} = T\,/\,^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 **(a)** A ball of mass 0.050 kg is dropped from rest onto a hard floor and bounces vertically repeatedly. The height from which the ball is dropped is measured to be 2.000 ± 0.001 m. Assume air resistance is negligible.

(i) Determine the speed of the ball, with its associated uncertainty, just before the first impact.

speed = ... ± ..... m s^{-1} [3]

(ii) The speed of the ball decreases by 30 % just after the first bounce.

1. Determine the corresponding momentum of the ball.

momentum = ... kg m s^{-1} [2]

2. Given that the duration of the first impact is 0.10 s, calculate the magnitude of the average force exerted on the ball by the floor.

force = ... N [2]

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(b) A rock climber is stranded on a ledge. The rescuer on the ground shoots a rescue kit to him. The rescue kit is directed at an initial angle of 60° above the horizontal and has a launch speed of 17 m s^{-1}. Assume air resistance is negligible.

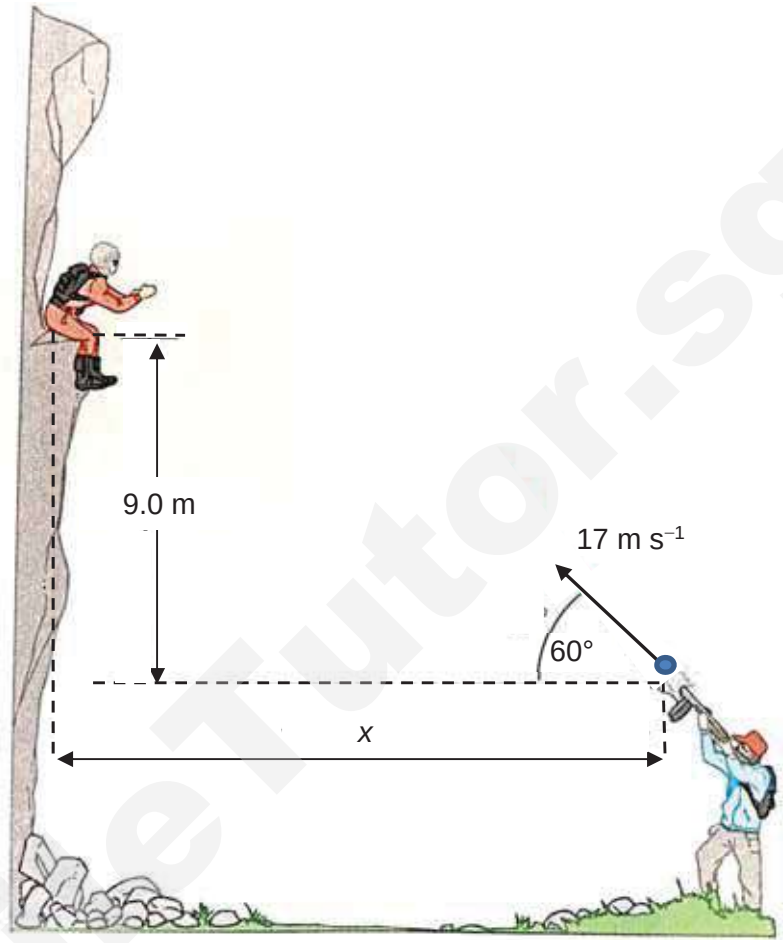

Fig. 1.1 (not drawn to scale)

(i) The kit reaches the top of its trajectory and then falls towards the climber.

Determine the time the kit takes to reach the climber.

time = ... s [2]

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(ii) Hence, determine the horizontal distance x travelled by the kit.

x = ... m [1]

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2 **(a)** State what is meant by an *ideal gas*.

.....

..... [1]

(b) **(i)** A tyre is filled with air at a temperature of 15 °C and a pressure of 220 kPa.

If the tyre reaches a temperature of 38 °C, calculate the fraction of the original amount of air that must be removed to maintain the original pressure of 220 kPa. Assume the air to be ideal.

fraction = ... [3]

(ii) If the pressure of the air in a sealed tyre is doubled while its volume is held constant, calculate the ratio of the new root-mean-square speed to the original root-mean-square speed of the air molecules.

ratio = ... [2]

(c) Explain how molecular movement causes the pressure exerted by a gas.

.....

.....

.....

.....

..... [3]

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3 **(a)** The wavelength of the monochromatic light from a source can be determined using the experimental setup as shown in Fig. 3.1. The slit separation *a* is 0.030 mm and the distance between the double slits and the screen *D* is 1.2 m.

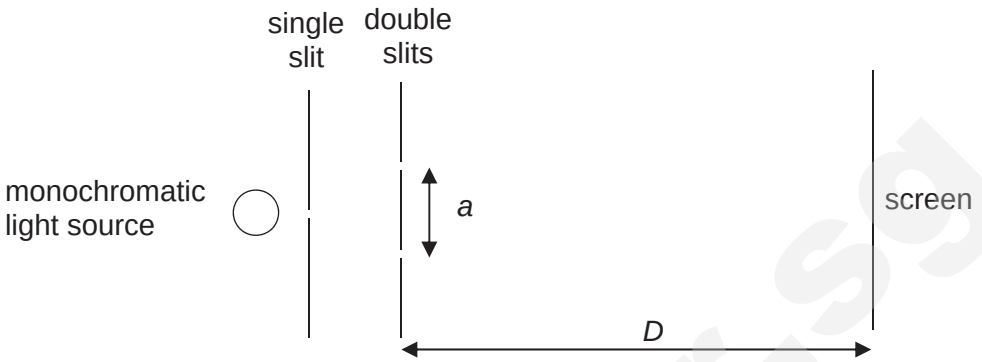

Fig. 3.1

When the monochromatic light is incident on the slits, the separation of the bright fringes on the screen is 1.7 cm.

(i) Calculate the wavelength of the monochromatic light source.

wavelength = ... m [2]

(ii) The following changes are made independently. Describe, in each case, the effect on the fringe separation and on the contrast between dark and bright fringes.

1. The distance *D* is increased to 2*D*, keeping *a* and λ constant.

.....

..... [2]

2. The monochromatic light source is changed to red light, keeping *a* and *D* constant.

.....

..... [2]

3. A polariser is placed between the single slit and the double slits.

.....

..... [2]

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(b) A diffraction grating with 450 lines per millimetre is placed in front of a white light source. The first order violet light emerges at an angle of 11.6° and the first order red light at an angle of 15.8°.

(i) Calculate the wavelength of these two colours.

wavelength of violet light = ... m

wavelength of red light = ... m [2]

(ii) Determine if any overlap of the spectrum can be observed.

[2]

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4 A charged metal sphere is isolated in space. Measurements of the electric potential V are made for different distances x from the centre of the sphere. The variation with distance x of the electric potential V is shown in Fig. 4.1.

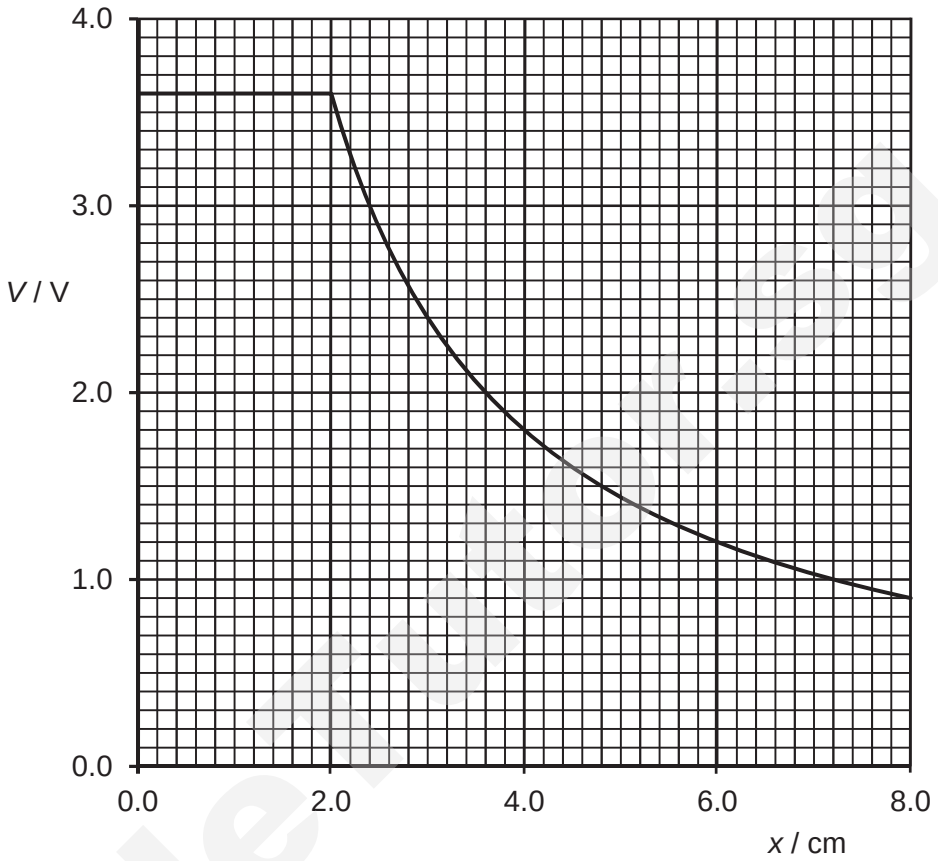

Fig. 4.1

(a) By making reference to electric fields, explain why the electric potential is constant for distances between $x = 0$ and $x = 2.0$ cm.

.....

.....

..... [2]

(b) Calculate the charge on the sphere.

charge = ... C [2]

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(c) Calculate the total electric potential at x = 4.0 cm if a particle of charge -7.2×10^{-12} C is placed at x = 6.0 cm.

electric potential = ... V [3]

(d) The particle of charge -7.2×10^{-12} C accelerates upon release from rest at x = 6.0 cm.

(i) Without any calculations, describe the acceleration of the particle in terms of its magnitude and direction.

.....

.....

..... [2]

(ii) Calculate the kinetic energy of the particle after moving a distance of 2.0 cm.

kinetic energy = ... J [2]

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5 A battery of e.m.f. E and internal resistance of 3.0 Ω is connected to a variable resistor of resistance R, as shown in Fig. 5.1.

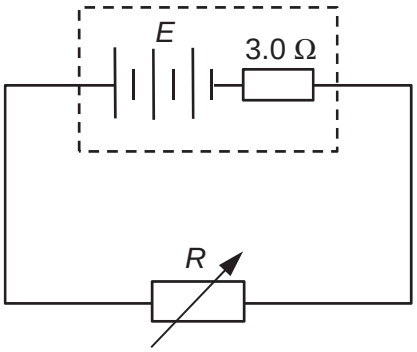

Fig. 5.1

The resistance R in the circuit is varied. The variation with R of the power P dissipated in the variable resistor is shown in Fig. 5.2.

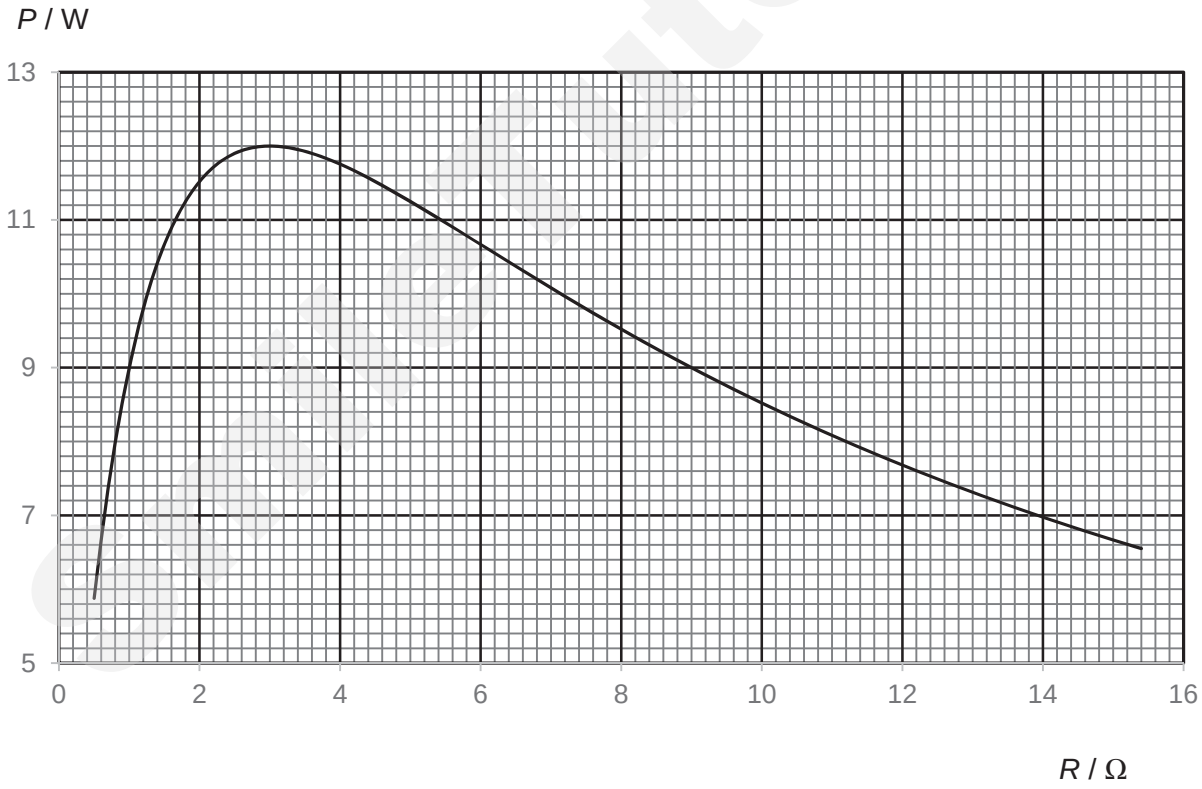

Fig. 5.2

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(a) When R = 14.0 Ω, calculate

(i) the current in the circuit,

current = ... A [2]

(ii) the e.m.f. E of the battery,

E = ... V [2]

(iii) the total energy supplied by the battery in 10 minutes.

energy = ... J [2]

(b) State the value of R at which the power dissipated in the variable resistor is a maximum.

R = ... Ω [1]

(c) With reference to Fig. 5.2, explain why the graph has a maximum value.

……..

……..

……..

…… [2]

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(d) If the battery has negligible internal resistance, sketch the variation with R of the power P dissipated in the variable resistor on Fig. 5.3.



Fig. 5.3

[1]

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6 Fig. 6.1 shows the cross-section of a long straight wire. Current in the wire is flowing out of the plane of the paper.



Fig. 6.1

(a) On Fig. 6.1, sketch the magnetic flux pattern due to the current in the wire. [2]

(b) An electron is projected with a speed of 1.5×10^7 m s^{-1} towards the wire, at a perpendicular distance of 2.0 cm from the wire, as shown in Fig. 6.2. A current of 3.0 A is flowing in the wire.

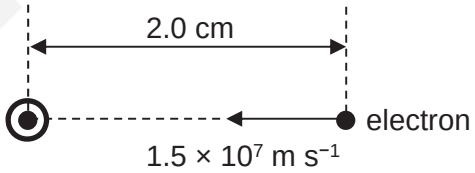

Fig. 6.2

(i) Show that the magnitude of the magnetic flux density at a perpendicular distance of 2.0 cm from the wire is 3.0×10^{-5} T.

[1]

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(ii) A magnetic force acts on the electron the moment it is projected towards the wire.

1. State the direction of the magnetic force.

…… [1]

2. Calculate the magnitude of the magnetic force.

magnetic force = ... N [2]

(c) A flat circular coil of radius 1.3 cm is placed near the straight wire, with its centre at a perpendicular distance of 2.0 cm from the wire, as shown in Fig. 6.3. A current of 3.0 A flows through the circular coil.

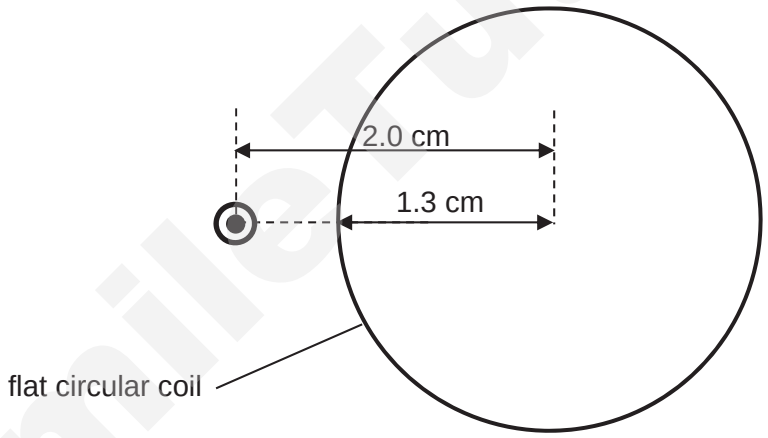

Fig. 6.3

Calculate the magnitude of the resultant magnetic flux density at the centre of the circular coil.

magnetic flux density = ... T [3]

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7 A piston of mass m is fixed to a light spring in a frictionless cylinder of air as shown in Fig. 7.1. The cylinder is clamped tightly in place. At equilibrium position, the spring has an extension x_0. The piston is then displaced downwards by a vertical displacement x from the equilibrium position and released. The piston-spring system starts to oscillate.

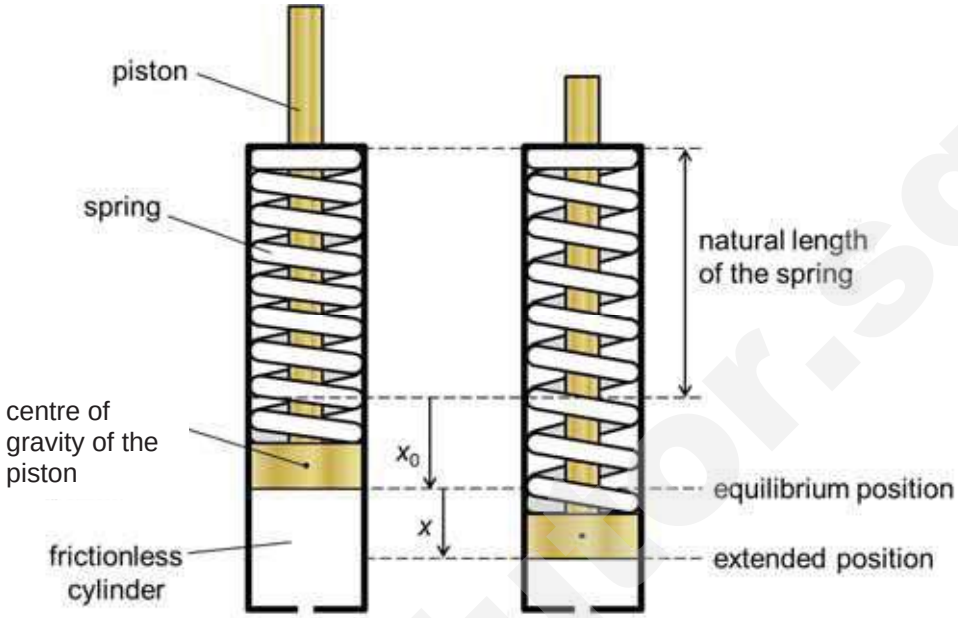

Fig. 7.1

(a) (i) On Fig. 7.2, draw and label the forces acting on the piston when the piston is displaced a vertical displacement x below the equilibrium position.

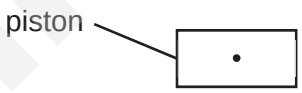

Fig. 7.2

[1]

(ii) Taking downwards as positive, use Newton's second law of motion to derive an equation for the acceleration a of the piston in terms of its mass m, the spring constant of the spring k and its displacement x from the equilibrium position. Show your working clearly.

[2]

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(iii) Explain how the equation in **(ii)** shows that the piston oscillates with simple harmonic motion.

.....

.....

.....

..... [2]

(b) The piston-spring system is now fixed in a large reserve cylinder that is filled with oil as shown in Fig. 7.3. The reserve cylinder is clamped tightly in place.

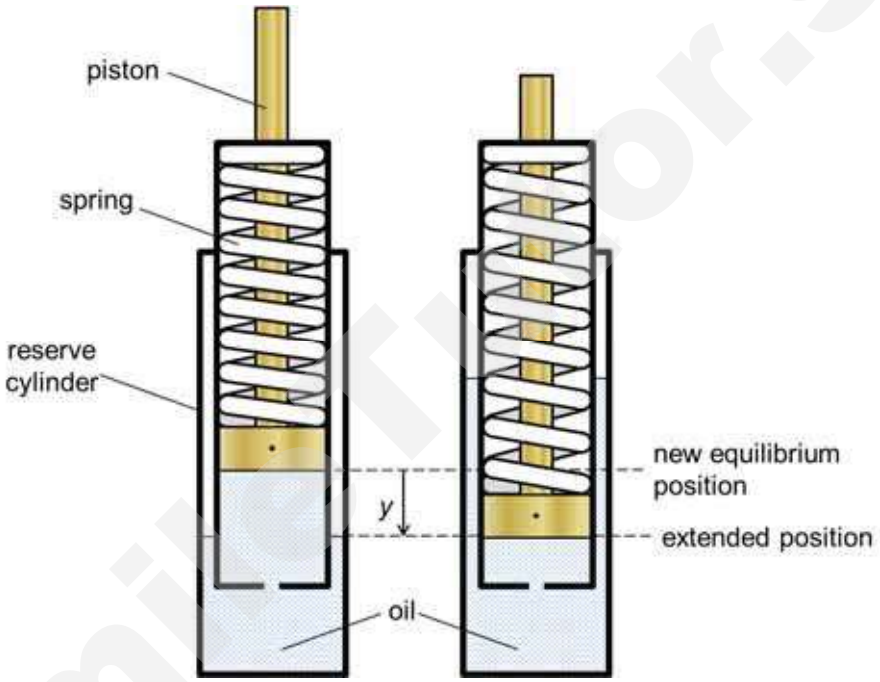

Fig. 7.3

The piston is displaced downwards with an initial displacement of y = 4.0 cm and released. Fig. 7.4 shows the variation with time t of the displacement y of the oscillations of the piston.

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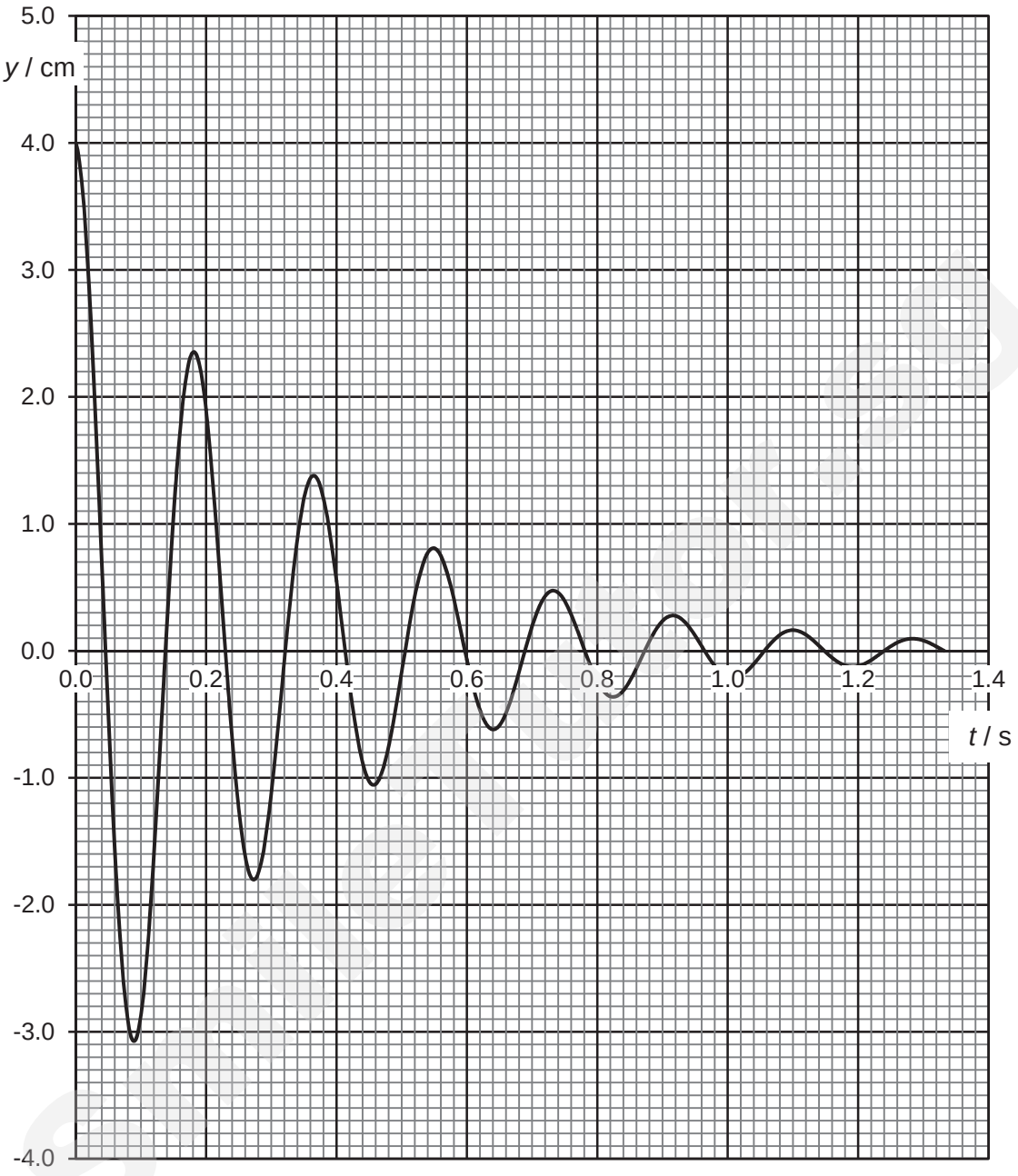

Fig. 7.4

(i) State and explain whether the damping of the piston is light, heavy or critical.

.....

.....

..... [2]

(ii) Use Fig. 7.4 to deduce the amplitude of the oscillation of the piston at t = 0.50 s.

amplitude = ... cm [1]

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(c) It is suggested that the amplitude of the oscillation decreases exponentially with time according to the relationship

$$A = A_0 e^{-2\pi f_n \gamma t}$$

where A_0 is the amplitude at t = 0 and A is the amplitude at t. The constant γ is dependent on the fluid that produces the damping of the oscillating piston. The constant f_n is the natural frequency of the oscillating piston.

An experiment is carried out to determine γ. Fig. 7.5 shows some data obtained from Fig. 7.4.

t / s	A / cm	ln(A / cm)
0	4.00	1.386
0.18	2.35	0.854
0.37		
0.55	0.81	−0.21
0.73	0.47	−0.76
0.92	0.28	−1.27
1.10	0.16	−1.83

Fig. 7.5

(i) Use Fig. 7.4 to complete Fig. 7.5 for t = 0.37 s. [1]

(ii) Fig. 7.6 is a graph of some of the data of Fig. 7.5.

On Fig. 7.6,

1. plot the point corresponding to t = 0.37 s,

2. draw the line of best fit for all points.

[2]

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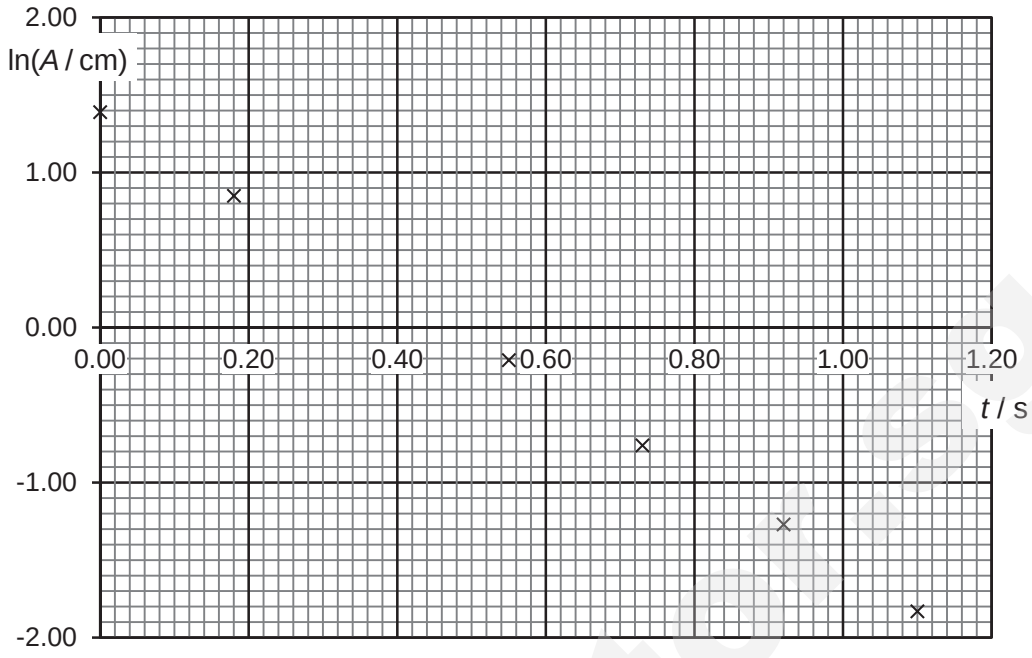

Fig. 7.6

(iii) Determine the gradient of the line drawn in **(ii)**.

gradient = ... [2]

(iv) Explain why the graph in Fig. 7.6 supports the expression given in **(c)**.

.....

.....

.....

..... [2]

(v) Use Fig. 7.4 to determine the constant f_n.

f_n = ... Hz [1]

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(vi) Determine the constant γ.

γ = ... [1]

(d) Damping systems like these are often used in motor vehicle suspension systems.

If the damping coefficient γ is a measure of damping of the vehicle suspension system, suggest with a reason whether the magnitude of γ is likely to be higher or lower than that in **(c)(vi)**.

.....

.....

.....

..... [2]

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End of paper

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Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/03**
Higher 2

Paper 3 Longer Structured Questions

19 September 2017

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question only.

You are advised to spend about one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
1		/	9
2		/	9
3		/	8
4		/	7
5		/	7
6		/	9
7		/	11
8		/	20
9			20
Total		/	80

This document consists of **25** printed pages.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T\,/\,\mathrm{K} = T\,/\,^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** Distinguish between *gravitational potential energy* and *elastic potential energy*.

gravitational potential energy: ……

……

elastic potential energy: ……

…… [2]

(b) A spring is attached horizontally to a movable light slider at point A and a fixed support at point B, as shown in Fig. 1.1.

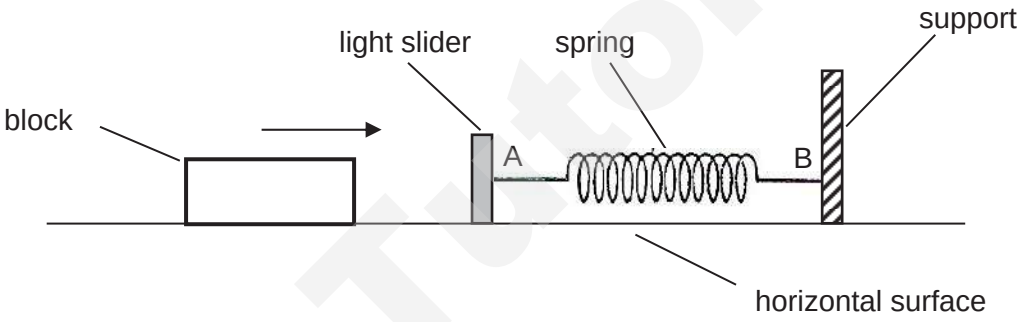

Fig. 1.1

A block of mass 1.7 kg moves towards the slider and collides with the slider, compressing the spring. The variation with force *F* exerted on the spring of the compression *x* of the spring is shown in Fig. 1.2. The block comes to a rest momentarily when *F* is 4.5 N.

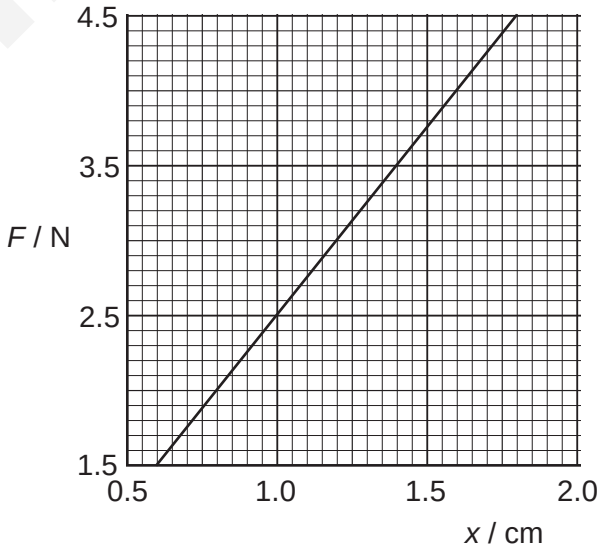

Fig. 1.2

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(i) Calculate the spring constant of the spring.

spring constant = ... N m^{-1} [2]

(ii) Calculate the elastic potential energy stored in the spring when the block is at rest momentarily.

elastic potential energy = ... J [2]

(iii) The frictional force between the block and the horizontal surface is 1.2 N.

Calculate the speed of the block when it first makes contact with the slider.

speed = ... m s^{-1} [3]

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2 **(a)** Define *gravitational field strength* and state an appropriate unit for it.

.....

..... [2]

(b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.97×10^{24} kg concentrated at its centre, as shown in Fig. 2.1.

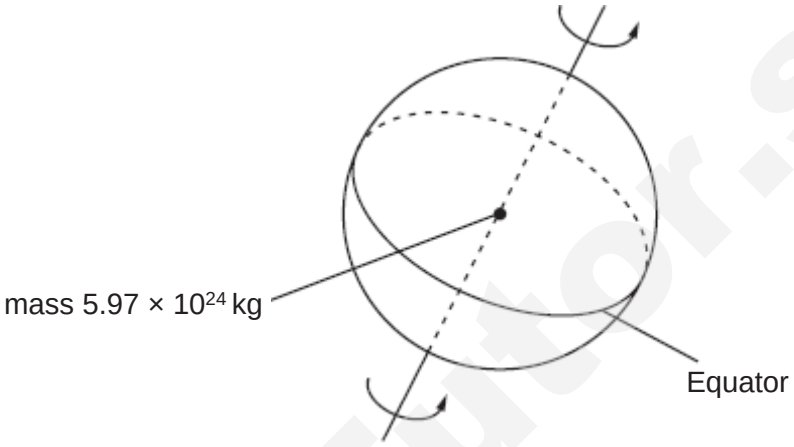

Fig. 2.1

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 8.65×10^4 s.

(i) Use Newton's law of gravitation to calculate the gravitational force of attraction between the 1.00 kg mass and the Earth.

gravitational force= ..... N [2]

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(ii) Determine the centripetal force on the 1.00 kg mass.

centripetal force = ... N [2]

(iii) Hence, determine the acceleration of free fall at the Equator

acceleration of free fall = ... m s^{-2} [2]

(iv) The acceleration of free fall at the Equator is not equal to the acceleration of free fall at the poles.

Explain why they are different.

.....

..... [1]

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3 **(a)** State what is meant by *specific latent heat of fusion*.

.....

.....

..... [2]

(b) 30 g of ice at −15 °C is taken from a freezer and placed in a Styrofoam cup containing 200 g of water at 28 °C. Data for ice and for water are given below.

Specific heat capacity of ice = 2.1×10^3 J kg^{-1} K^{-1}
Specific heat capacity of water = 4.2×10^3 J kg^{-1} K^{-1}
Specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1}

Calculate the final temperature of the water in the Styrofoam cup. Assume negligible heat transfer to the surroundings.

temperature = ...°C [3]

(c) **(i)** State the *first law of thermodynamics*.

.....

.....

..... [1]

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(ii) A gas of volume 1.5 $\times 10^{-3}$ m^3 and at a pressure of 1.0 $\times$ 10^5 Pa is supplied with 50 J of thermal energy. Its volume increases to 1.7 $\times 10^{-3}$ m^3 with the pressure remaining constant.

Calculate the change in the internal energy of the gas.

change in internal energy = ... J [2]

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4 A microwaves transmitter is located a distance directly opposite an aerial, which is connected to a meter as shown in Fig. 4.1. Microwaves polarised in the vertical plane is incident on the aerial which is initially positioned vertically to give a maximum reading on the meter.

The aerial can subsequently be made to rotate through an angle θ in the vertical plane.

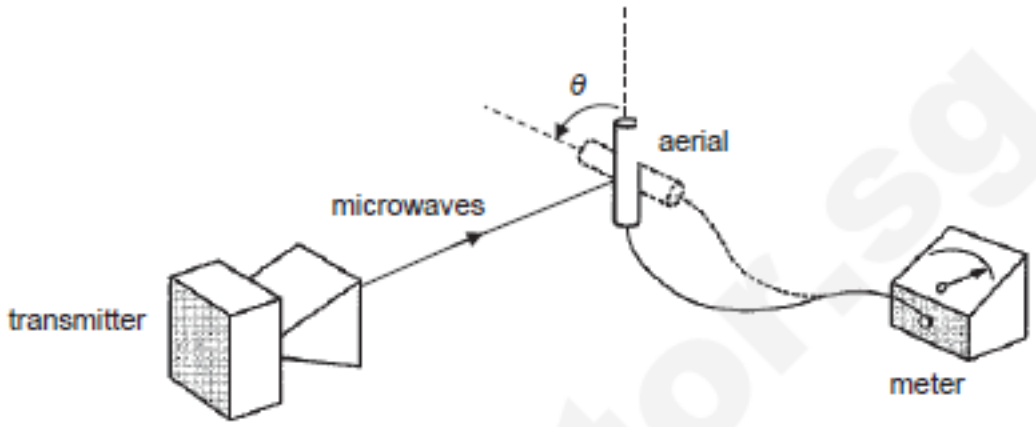

Fig. 4.1

(a) (i) When the angle θ through which the aerial is rotated is increased from 0° to 90°, describe and explain the variation, if any, in the meter reading.

.....

.....

..... [2]

(ii) State what the variation in meter reading, if any, suggest about the nature of microwaves.

..... [1]

(b) When the aerial is positioned vertically, the amplitude and intensity of the signal received is A and I respectively.

(i) Determine the smallest angle θ through which the aerial must be rotated so that the amplitude of the signal received is $\frac{A}{2}$.

θ = ... ° [2]

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(ii) When the aerial is rotated such that the amplitude of the signal received is $\frac{A}{2}$, determine the intensity of the signal received in terms of I.

intensity = ... I [2]

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5 **(a)** State what is meant by *diffraction*.

……

……

…… [2]

(b) (i) A ripple tank is used to show the diffraction of water waves. On Fig. 5.1, plane wavefronts are shown approaching a single slit.

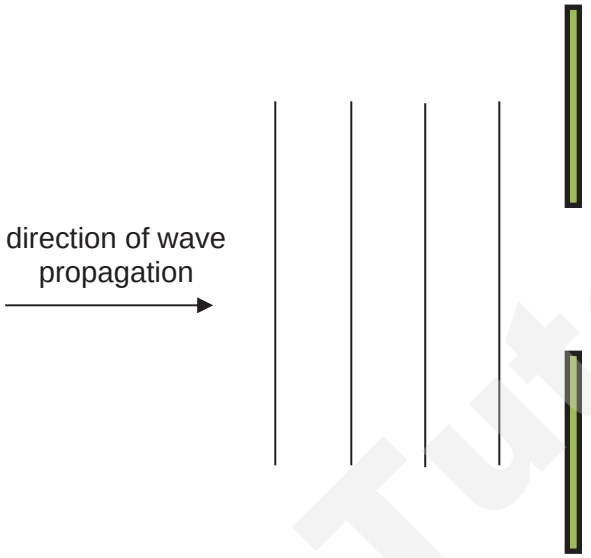

Fig. 5.1

On Fig 5.1, draw four wavefronts to show the waves after they have passed through the slit. [2]

(ii) The list is now made narrower as shown in Fig. 5.2.

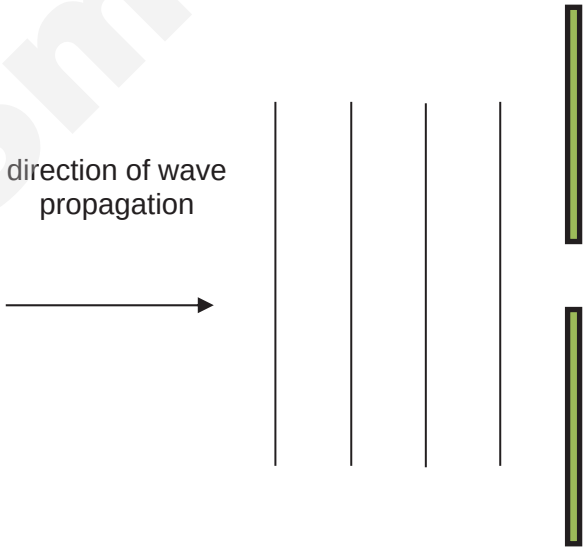

Fig. 5.2

On Fig. 5.2, draw four wavefronts to show the waves after they have passed through the narrower slit. [1]

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(c) The headlights of a car are 1.4 m apart. If the diameter of the pupil of the eye is 2.5 mm, calculate the distance at which the images of the two headlights are just resolved. (Assume the headlights are point sources of wavelength of 500 nm.)

distance = ... m [2]

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6 **(a)** An ammeter whose internal resistance is 63 Ω reads 5.25 mA when connected in a circuit containing a battery and two resistors in series. The two resistors have resistances 750 Ω and 480 Ω respectively.

Calculate the current in the circuit when the ammeter is absent.

current = ... mA [2]

(b) Fig. 6.1 shows a cell of e.m.f. 2.0 V and internal resistance 0.20 Ω connected in parallel to two identical lamps L_1 and L_2. The ammeters A_1 and A_2 in the circuit have negligible resistance and A_2 reads 0.50 A.

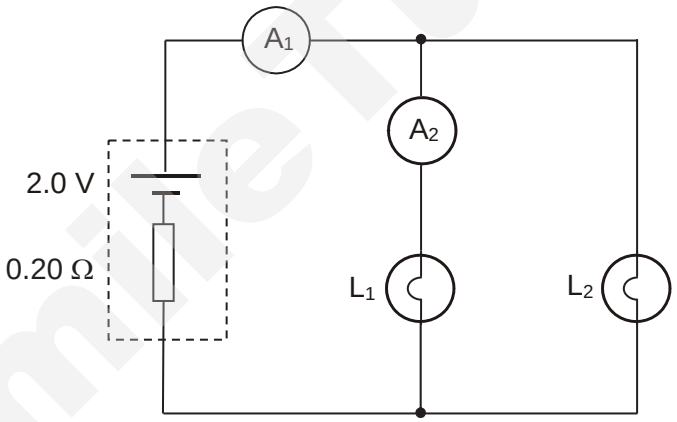

Fig. 6.1

(i) Calculate the potential difference across L_1.

potential difference = ... V [2]

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(ii) If another identical lamp L_3 is connected in parallel with L_1 and L_2, explain whether the current in ammeter A_1 remains the same, increases or decreases.

.....

.....

..... [2]

(c) A new circuit is set up as shown in Fig. 6.2. A 1.0 m potentiometer wire AB of resistance 3.0 Ω is connected across the 2.0 V cell. Another cell of e.m.f 0.50 V and negligible internal resistance is included in the circuit. A resistor X is connected in series to the 2.0 V cell and balance length of 0.80 m is obtained.

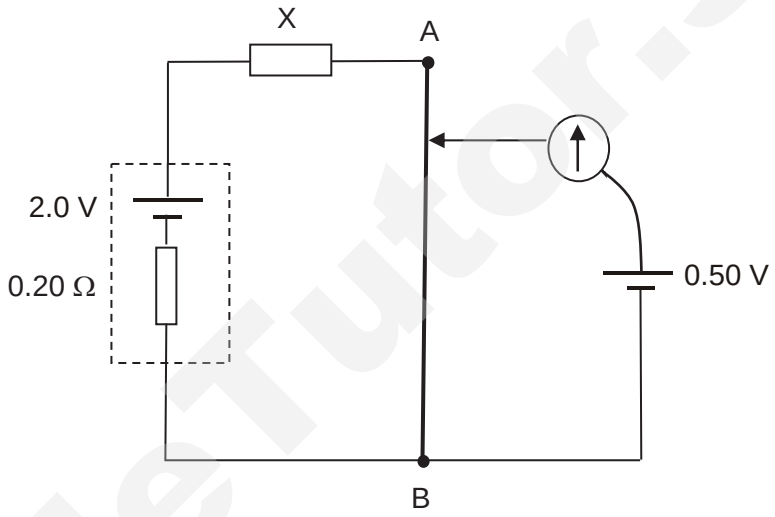

Fig. 6.2

Calculate the resistance of resistor X.

resistance = ... Ω [3]

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7 **(a)** Explain what is meant by a *photon*.

……..

……..

…… [2]

(b) Light of wavelength 350 nm is incident on a metal surface. The work function energy of the metal is 2.46 eV.

(i) Show that electrons are emitted with a maximum speed of 6.2×10^5 m s^{-1}.

[2]

(ii) Determine the de Broglie wavelength of an electron at this speed.

de Broglie wavelength = …… m [2]

(c) The metal surface is replaced with zinc. Zinc has a work function energy of 4.31 eV.

(i) Determine whether electrons will be emitted.

[2]

(ii) Explain whether your conclusion in **(i)** is affected by the intensity of light.

……...

……...

…… [1]

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(d) Explain how the line spectra provide evidence for discrete energy levels in isolated atoms.

……

……

……

…… [2]

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Section B

Answer **one** question in this section in the spaces provided.

8 **(a)** A square coil of wire of side *s* falls vertically through a uniform magnetic field of flux density *B* with speed *v*. The wire has uniform cross-sectional area *A* and resistivity ρ. The field is directed normally into the plane of the coil, as shown in Fig. 8.1.

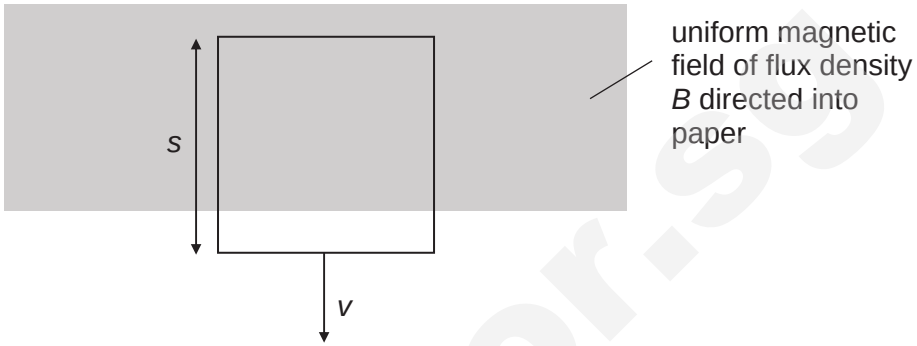

Fig. 8.1

As the coil leaves the region of uniform magnetic field, a current flows in the coil.

(i) Explain why a current flows in the coil as it leaves the region of uniform magnetic field.

.....

.....

..... [2]

(ii) On Fig. 8.1, indicate the direction of the current in the coil. [1]

(iii) Show that the current I in the coil is given by the expression

$$I = \frac{BvA}{4\rho}$$

.

[2]

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(iv) After some time, before it completely leaves the region of magnetic field, the coil falls with a constant speed.

Explain why the coil falls with a constant speed.

.....

.....

.....

.....

..... [3]

(v) Calculate the constant speed for the coil given that B has a magnitude of 2.0 T and the coil is made of a metal of resistivity 1.5×10^{-6} Ω m and density 8400 kg m^{-3}.

speed = ... m s^{-1} [3]

(b) Another square coil of side 20 cm made from the same metal wire is now rotated about an axis PQ at a uniform rate of 5 revolutions per second in the same uniform magnetic field as shown in Fig. 8.2. The wire has a diameter of 0.10 cm. An e.m.f. is generated in the coil when it rotates

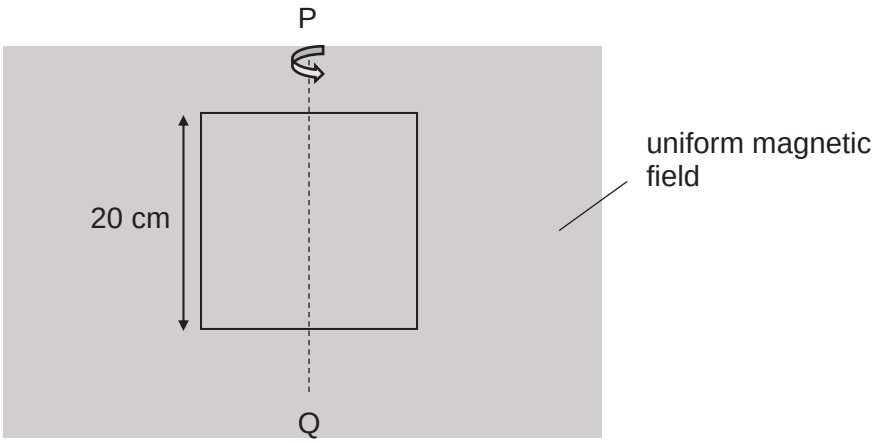

Fig. 8.2

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(i) Explain why the e.m.f. is sinusoidal.

.....

.....

..... [2]

(ii) At time $t = 0$, the area of the coil is perpendicular to the magnetic field.

1. On Fig. 8.3, sketch a graph, with appropriate values, to show the variation with time of the magnetic flux Φ through the coil for at least two cycles.



Fig. 8.3

[3]

2. On Fig. 8.4, sketch a corresponding graph, with appropriate values, to show the variation with time of the induced e.m.f. generated in the coil.



Fig. 8.4

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(iii) Calculate the root-mean-square current in the coil.

current = ... A [2]

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9 **(a)** Nuclear fusion is a nuclear reaction in which two or more atomic nuclei collide at very high speed and fuse to form a larger nucleus. Fusion of light nuclei yields considerable amount of energy and can serve as potential energy sources for the Earth. One of the most promising is the fusion of deuterium and tritium, which results in the formation of a stable helium nuclide. Each deuterium-tritium fusion reaction yields 17.59 MeV of energy, accompanied by the release of a single neutron.

Deuterium (${}^{2}_{1}\mathrm{H}$) and tritium (${}^{3}_{1}\mathrm{H}$) are isotopes of hydrogen.

(i) State what is meant by *binding energy* of a nucleus.

.....

..... [1]

(ii) On Fig. 9.1, sketch the variation with nucleon number A of the binding energy per nucleon B_E. Indicate the maximum value of B_E and the corresponding value of A.



Fig. 9.1

[2]

(iii) Explain why fusion of nuclei having high nucleon numbers is not associated with a release of energy.

.....

.....

.....

..... [2]

(iv) Complete the nuclear equation for the deuterium-tritium fusion reaction below.

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{He} + {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{n} $$

[1]

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(v) Some data for the reaction in **(iv)** are given.

binding energy per nucleon of $^{2}_{1}H$ = 1.112 MeV
binding energy per nucleon of $^{3}_{1}H$ = 2.827 MeV
rest mass of proton = 1.00728 u
rest mass of neutron = 1.00866 u

1. Show that the binding energy of the helium nucleus in **(iv)** is 28.295 MeV.

[2]

2. Hence, calculate the mass of the helium nucleus.

mass = ... kg [3]

(b) The radioactive decay of the isotope bismuth-210 is both spontaneous and random.

(i) Explain what is meant by *spontaneous* decay.

.....

..... [1]

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(ii) Bismuth-210 ($^{210}_{84}Bi$) undergoes β^--decay to form polonium (Po). When the velocities of the β^--particles are measured, it is found that there is a continuous distribution of velocities up to a maximum. Fig. 9.2 shows the variation with energy of the number of β^--particles.

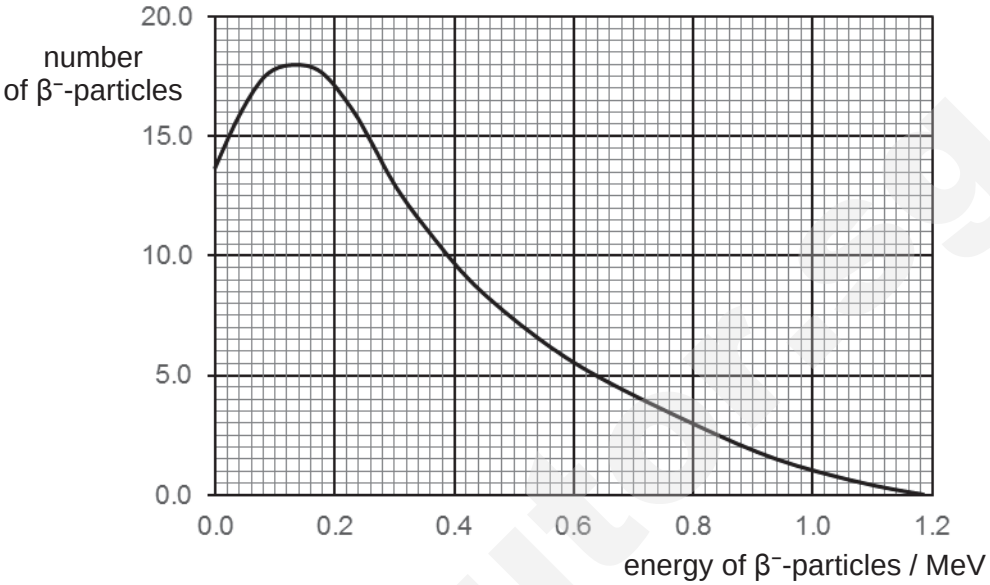

Fig. 9.2

Explain why there is a continuous distribution of energy among the β^--particles.

.....

.....

.....

.....

.....

..... [3]

(iii) The isotope bismuth-212 ($^{212}_{83}Bi$) undergoes spontaneous α-particle decay. The energy of the α-particles emitted is 6.42 MeV.

Suggest, with a reason, which of the two isotopes, bismuth-210 or bismuth-212, has the larger decay constant.

.....

.....

.....

..... [3]

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(c) Polonium itself is radioactive and decays by the emission of α-particles. The polonium decays to form lead (Pb) which is stable. The half-life of polonium is 138 days.

A sample of bismuth-210 is stored for a time of 150 days in a lead container. The half-life of bismuth-210 is 5.0 days.

The number of polonium nuclei is almost equal to the number of lead nuclei.

By reference to the half-lives, explain this observation.

……

……

…… [2]

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End of paper

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Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9749/04**
Higher 2

Paper 4 Practical Paper

29 August 2017

2 hours 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 9
2	/ 14
3	/ 20
4	/ 12
Total	/ 55

This document consists of **14** printed pages.

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1 In this experiment, you will investigate the extension of a rubber band.

(a) Set up the retort stand as shown in Fig. 1.1. Hang the rubber band from the rod and the mass hanger on the lower end of the rubber band.

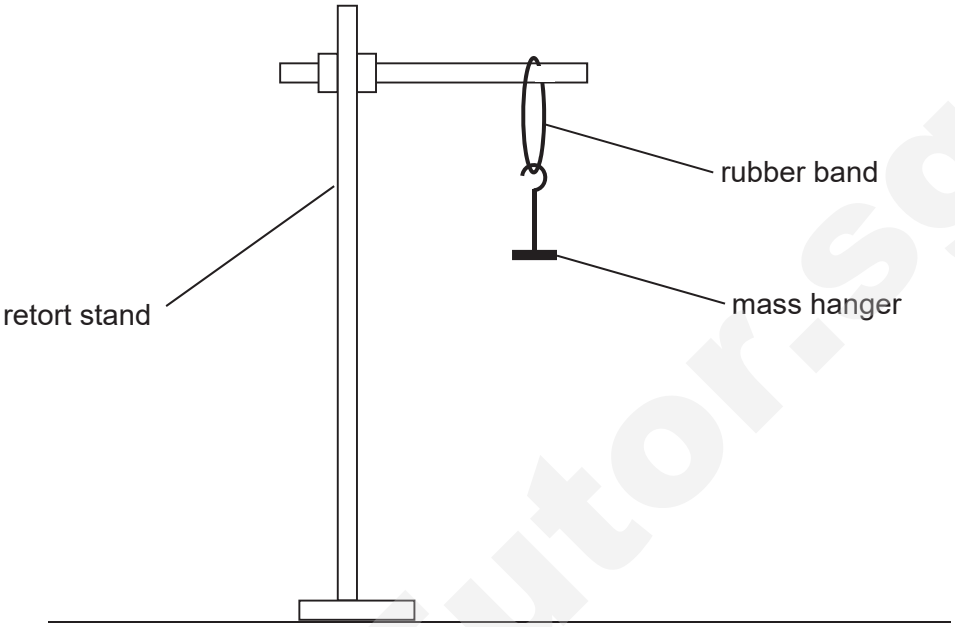

Fig. 1.1

(b) (i) Measure and record the length l of the rubber band.

l = ... [1]

(ii) Estimate the percentage uncertainty in this value of l.

percentage uncertainty = ... [2]

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(c) Record five more readings of l and mass m up to a value of m = 300 g.
When increasing the mass, ensure that the rubber band is not allowed to slacken.

[2]

(d) Plot your values from **(c)** on Fig. 1.2. The graph obtained should be a curve.



Fig. 1.2

[2]

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(e) Based on your graph in Fig. 1.2, comment on the spring constant of the rubber band.

.....

.....

.....

..... [2]

[Total: 9 marks]

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2 In this experiment, you will investigate how the potential difference across a current-carrying wire depends on its diameter.

(a) Measure and record the diameter d of wire A.

d = ... [1]

(b) Connect the circuit shown in Fig. 2.1. The wire A should be connected into the circuit using crocodile clips placed close to the ends of the wire.

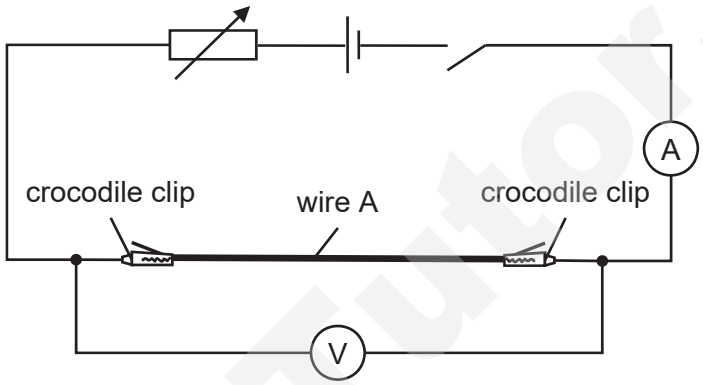

Fig. 2.1

(c) (i) Measure and record the length L of wire between the crocodile clips.

L = ... [1]

(ii) Estimate the percentage uncertainty in your value of L.

percentage uncertainty = ... [1]

(d) (i) Close the switch. Adjust the variable resistor until the current is close to 90 mA. Record this current I.

I = ...

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(ii) Record the voltmeter reading V and then open the switch.

V = ... [1]

(e) Measure and record the diameter d of wire B.

d = ... [1]

(f) **(i)** In the circuit, replace wire A with wire B, maintaining the same length L of the wire between the crocodile clips as in **(c)(i)**.

(ii) Close the switch. Adjust I to the same value as in **(d)(i)**. Record V and then open the switch.

V = ... [1]

(g) It is suggested that the relationship between V, L and d is

$$V = \frac{kL}{d^2}$$

where k is a constant.

(i) Using your data, calculate two values of k.

value of k for wire A = ...

value of k for wire B = ... [2]

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(ii) Justify the number of significant figures that you have given for your values of *k*.

……

……

…… [1]

(iii) Explain whether your results support the suggested relationship.

……

……

……

……

…… [1]

(h) (i) Describe two sources of uncertainty or limitations of the procedure in this experiment.

1. ……

……

2. ……

…… [2]

(ii) Describe two improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1. ……

……

2. ……

…… [2]

[Total: 14 marks]

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3 In this experiment, you will investigate how the period of a spring pendulum varies with load.

(a) Set up the apparatus as shown in Fig. 3.1.

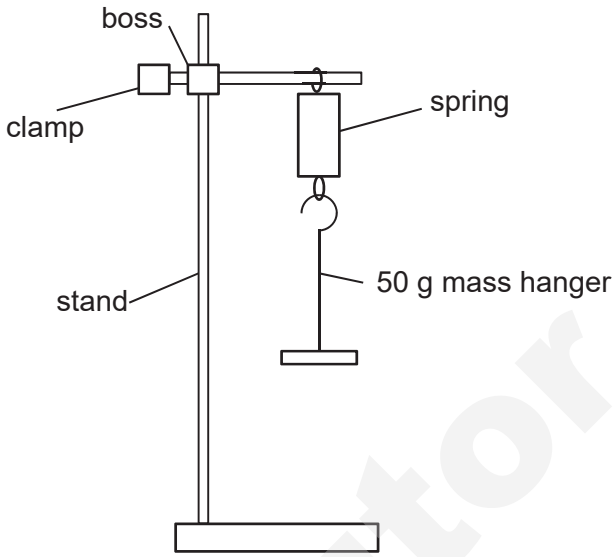

Fig. 3.1

(b) Pull the mass **horizontally**.

Release the mass and allow it to oscillate.

Take measurements to determine the period T of these oscillations.

T = ... [1]

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(c) Vary the mass m suspended from the spring and repeat **(b)** for further values of m.

Record values of m, T, lg m and lg T.

[6]

(d) It is suggested that T and m are related by the expression

$$T = am^b$$

where a and b are constants.

(i) Plot a graph of lg T against lg m.

(ii) Determine the gradient of the line.

gradient = ... [2]

(iii) Determine the y-intercept of the line.

y-intercept = ... [2]

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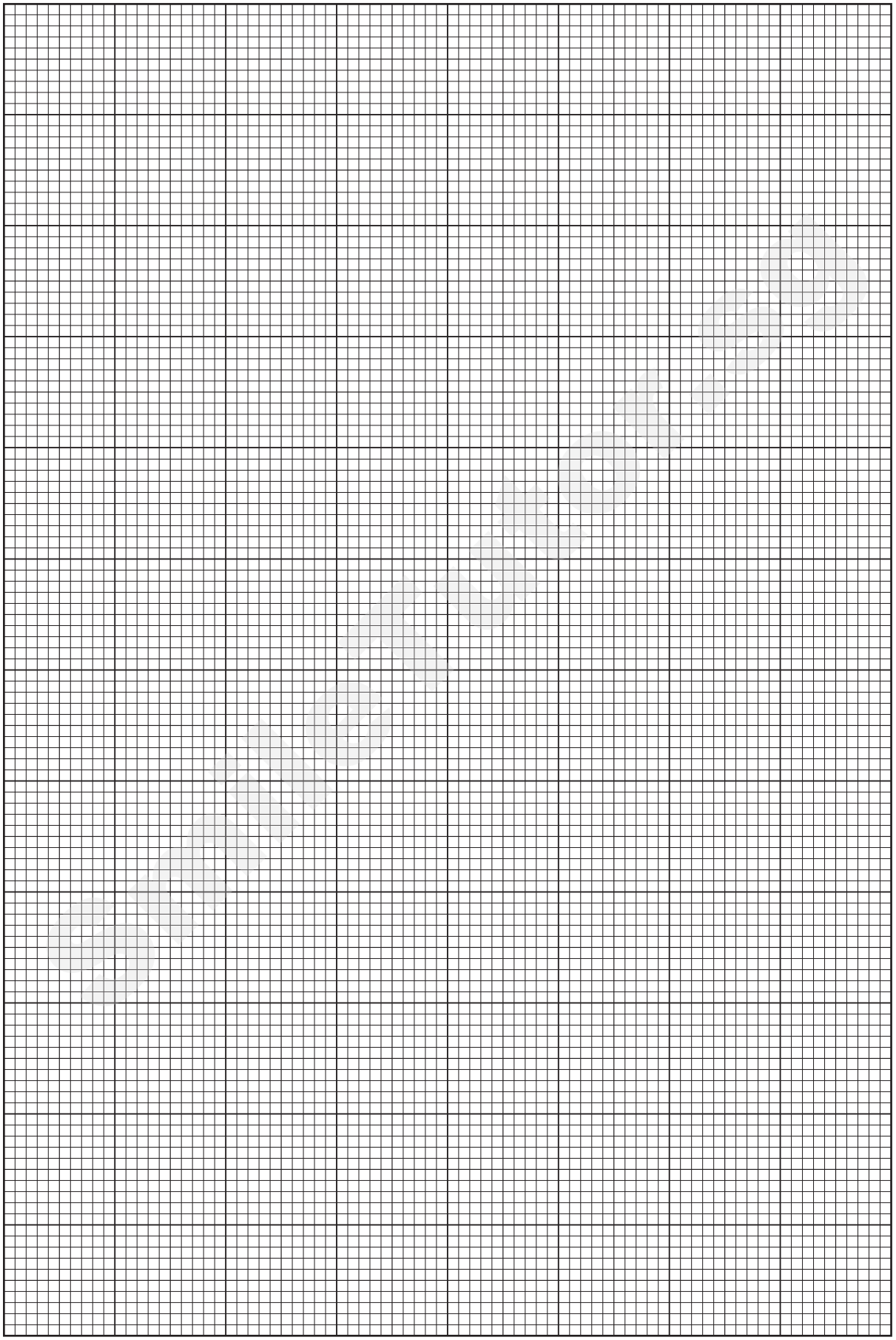

[3]

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(e) Use values from **(d)(ii)** and **(d)(iii)** to determine values for *a* and *b*.

a = ... [1]

b = ... [1]

(f) Identify any anomalous observation.

Suggest a cause for the anomaly identified.

…..

…..

…..

……..... [2]

(g) (i) Calculate the value of *T* when *m* = 1500 g.

T = ... [1]

(ii) Identify a problem with determining an experimental value of *T* when *m* = 1500 g.

.....

.....

..... [1]

[Total: 20 marks]

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4 A student is investigating the characteristics of different light-emitting diodes (LEDs). Fig. 4.1 shows examples of LEDs and the circuit symbol for an LED.

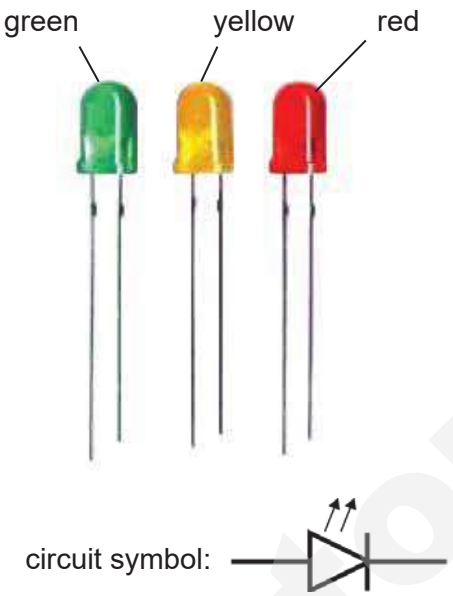

Fig. 4.1

Each LED needs a minimum potential difference V across it to emit light. The student is investigating the relationship between V and the wavelength λ of the light emitted by the LED for several different LEDs.

It is suggested that the relationship is

$$V = k\lambda^n$$

where k and n are constants.

You are provided with a number of LEDs of different wavelengths. You may use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between V and λ.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedure to be followed,

(d) how the relationship between V and λ is determined from your readings and how measurements of λ are to be determined,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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.....

.....

.....

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PJC Answers to JC2 Preliminary Examination Paper 1 (H2 Physics)

1	**A**	**6**	**B**	**11**	**D**	**16**	**C**	**21**	**C**	**26**	**C**
2	**D**	**7**	**C**	**12**	**D**	**17**	**B**	**22**	**B**	**27**	**D**
3	**C**	**8**	**C**	**13**	**A**	**18**	**A**	**23**	**D**	**28**	**A**
4	**B**	**9**	**B**	**14**	**B**	**19**	**C**	**24**	**A**	**29**	**A**
5	**A**	**10**	**D**	**15**	**D**	**20**	**C**	**25**	**D**	**30**	**B**

Suggested Solutions:

1 1 m s^{-1} = 3.6 km h^{-1}
1 m = 0.001 km

$$k = \frac{s}{v^2}$$

Since speed is measured in kilometres per hour, and the distance is measured in kilometres,

$$\text{value of constant} = \frac{0.001}{3.6^2}k_1$$
$$= 7.72 \times 10^{-5} k_1$$

Answer: A

2 Gradient of graph gives the velocity. Graph D shows the speed of the object increasing from zero to a constant maximum value.

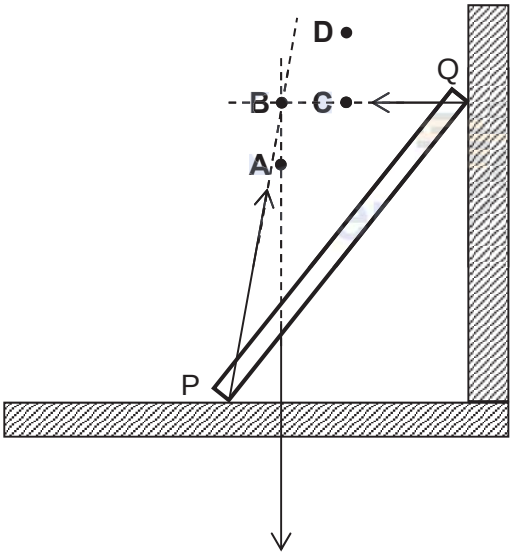
Answer: D

3 $\text{Resultant force} = (m+M)a$

$$(m+M)a = (m+M)g\sin\theta - F$$
$$F = (m+M)g\sin\theta - (m+M)a$$
$$= (m+M)(g\sin\theta - a)$$

Answer: C

4



Answer: B

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5 $P = Fv$

Since both F and v increases with time, P increases at an increasing rate.

Answer: A

6 Let new angular velocity be ω' and original angular velocity be ω.

$$\text{period} = 24 \times 60 \times 60$$
$$= 8.64 \times 10^4 \text{ s}$$

$$\text{percentage change} = \frac{\omega' - \omega}{\omega} \times 100\%$$
$$= \frac{\frac{2\pi}{8.64 \times 10^4 + 6 \times 10^{-3}} - \frac{2\pi}{8.64 \times 10^4}}{\frac{2\pi}{8.64 \times 10^4}} \times 100\%$$
$$= -6.9 \times 10^{-6} \%$$

Answer: B

7 Gravitational force provides the centripetal force. Let mass of planet be M, mass of moon P be m_P and mass of moon Q be m_Q.

For P:

$$\frac{GMm_P}{(r_P)^2} = \frac{m_P (v_P)^2}{r_P}$$
$$GM = (v_P)^2 r_P \quad ---(1)$$

For Q:

$$\frac{GMm_Q}{(r_Q)^2} = \frac{m_Q (v_Q)^2}{r_Q}$$
$$GM = (v_Q)^2 r_Q \quad ---(2)$$

Solving (1) and (2):

$$\frac{v_P}{v_Q} = \left(\frac{r_Q}{r_P}\right)^{0.5}$$
$$= \left(\frac{2.3 \times 10^{10}}{1.4 \times 10^8}\right)^{0.5}$$
$$= 13$$

Answer: C

8 Since gravitational potential energy of satellite becomes less negative, there is an increase in potential energy and the satellite is moved further from the Earth.

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$$\text{Increase in gravitational potential} = \frac{-1600-(-4800)}{80}$$
$$= 40 \text{ MJ kg}^{-1}$$

Answer: C

9 Using $PV = nRT$. Since pressure is constant, $T \propto V$.
The values of T are measured in Kelvins and the graph cuts the origin.
Hence, if the values of T are measure in degree Celsius, the graph would shift downwards by −271.15.

Answer: B

10 For ideal gas, $pV = nRT$, $pV \propto T$,
The gas at lowest temperature has lowest internal energy and hence lowest root-mean-square speed.

At point A, pV = 4 units
At point B, pV = 12 units
At point C, pV = 6 units
At point D, pV = 2 units

Hence, point D has the lowest temperature and lowest root-mean-square speed.

Answer: D

11 Using $pV = NkT$,

$$p = \frac{N}{V}kT$$
$$N_v = \frac{N}{V} = \frac{p}{kT} \Rightarrow N_v \propto \frac{p}{T}$$
$$\frac{N'_v}{N_v} = \frac{p'}{T'}\left(\frac{T}{p}\right) = \frac{30}{300}\left(\frac{400}{60}\right)$$
$$N'_v = \frac{2N}{3}$$

Answer: D

12 Option A: The kinetic energy of the oscillator is proportional to **square of the frequency** of its motion. Incorrect.

Option B: The potential energy of the oscillator is **maximum** when the oscillator is momentarily at rest. Incorrect.

Option C: The kinetic energy of the oscillator is **maximum** when the oscillator is at the equilibrium position. Incorrect.

Option D: When the kinetic energy of the oscillator is equal to its potential energy, the oscillator is neither at the rest position nor at the maximum displacement positions. Correct.

Answer: D

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13 Acceleration of SHM given by
$a = -a_0 \sin(\omega t)$

Displacement of SHM given by
$x = x_0 \sin(\omega t)$

Ratio

$$\frac{x_{t=\frac{5T}{8}}}{x_0} = \frac{x_0 \sin(\frac{2\pi}{T} \times \frac{5T}{8})}{x_0}$$

$$= x_0 \sin(\frac{5\pi}{4})$$

$$= -0.71$$

Answer: A

14 In the same time duration when wave X completes one cycle of oscillations, wave Y completes two cycles. Hence frequency of wave Y is 2*f*.

Magnitude of maximum displacement of wave Y is half that of wave X. Hence, amplitude of wave Y is 0.5*A*.

Answer: B

15 Using $v = f\lambda$,

$$30 = 20\lambda$$

$$\lambda = 1.6\,\text{m}$$

$$\Delta\phi = \left(\frac{\Delta x}{\lambda}\right)2\pi$$

$$= \left(\frac{1.2}{1.6}\right)2\pi$$

$$= \left(\frac{3}{4}\right)2\pi$$

Hence the two points are out of phase by three quarters of a cycle.

Answer: D

16 First resonance is $\frac{1}{4}\lambda$, while second resonance is $\frac{3}{4}\lambda$.

Difference in the length = 0.45 – 0.18 = $\frac{1}{2}\lambda$

Therefore, wavelength of the sound wave is 0.54 m.

Answer: C

17 $I \propto A^2$

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Since waves are in anti-phase → resultant amplitude is *A*. Therefore intensity is I.

Answer: B

18 If the electric field strength is zero at a point, it only means that the electric potential gradient is zero at that point. The value of the electric potential at that point need not be zero.

Answer: A

19 For proton, $p = \sqrt{2meV}$

For alpha particle, $p' = \sqrt{2(4m)(2e)V} = 2\sqrt{2}p$

Answer: C

20

$$R_{wire} = \frac{\left(9.0\times10^{-8}\right)(100)}{\left(50\times10^{-6}\right)} = 0.18\ \Omega$$

Wires are in parallel,

$$R_{cable} = \frac{0.18}{4} = 0.045\ \Omega$$

Answer: C

21 $I = nqvA$

$= \left(8.5\times10^{28}\right)\left(1.60\times10^{-19}\right)\left(2.3\times10^{-5}\right)\left(8.6\times10^{-6}\right)$

$= 2.5$ A

Answer: C

22 p.d. across parallel branch = $E - I_1R_1$

$E - I_1R_1 = I_2R_2$

Answer: B

23 At null point, $E_2 = \frac{3R}{3R+2R+R}E_1$

Hence $\frac{E_1}{E_2} = 2.0$

Answer: D

24 For option A, the resultant force points towards conductor D.

Answer: A

25

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$$\varepsilon = \frac{(2)(50)\left(30\times10^{-4}\right)\left(4.0\times10^{-4}\right)\sin 60^0}{0.60}$$

$$= 1.7\times10^{-4} \text{ V}$$

Answer: D

26

$$I_S = \frac{V_S}{R} = \frac{210}{50} = 4.2 \text{ A}$$

The transformer is 60% efficient, so

$$I_S V_S = 0.6 I_P V_P$$

$$I_P = \frac{I_S V_S}{0.6 V_P} = \frac{I_S N_S}{0.6 N_P}$$

$$= \frac{(4.2)(100)}{0.6(20000)} = 0.035 \text{ A}$$

Answer: C

27 Velocity decreases → de Broglie's wavelength increases → more diffracted → larger diameter of circles

Answer: D

28 The energy of a photon of X-ray is much higher than the ionisation energy of hydrogen (13.6 eV).

Answer: A

29 Let R be the nucleus formed after the first stage decay.

Option A:

$${}^{A}_{Z}\text{P} \rightarrow {}^{A}_{Z+1}\text{R} + {}^{0}_{-1}e$$

$${}^{A}_{Z+1}\text{R} \rightarrow {}^{A}_{Z+1}\text{Q} + \gamma$$

Number of neutrons in nucleus Q $= A - (Z+1) = A - Z - 1$

Option B:

$${}^{A}_{Z}\text{P} \rightarrow {}^{A-4}_{Z-2}\text{R} + {}^{4}_{2}\text{He}$$

$${}^{A-4}_{Z-2}\text{R} \rightarrow {}^{A-4}_{Z-2}\text{Q} + \gamma$$

Number of neutrons in nucleus Q $= A - 4 - (Z-2) = A - Z - 2$

Option C:

$${}^{A}_{Z}\text{P} \rightarrow {}^{A-4}_{Z-2}\text{R} + {}^{4}_{2}\text{He}$$

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$^{A-4}_{Z-2}\mathrm{R} \rightarrow {}^{A-4}_{Z-1}\mathrm{Q} + {}^{0}_{-1}e$

Number of neutrons in nucleus $\mathrm{Q} = A - 4 - (Z - 1) = A - Z - 3$

Option D:

$^{A}_{Z}\mathrm{P} \rightarrow {}^{A}_{Z+1}\mathrm{R} + {}^{0}_{-1}e$

$^{A}_{Z+1}\mathrm{R} \rightarrow {}^{A}_{Z+2}\mathrm{Q} + {}^{0}_{-1}e$

Number of neutrons in nucleus $\mathrm{Q} = A - (Z + 2) = A - Z - 2$

Answer: A

30 Beta radiation can be stopped by 1 mm of aluminium (diagram 1), deflects towards the positively charged plate (diagram 2) and traces an anti-clockwise circular arc in a magnetic field into the page (diagram 3).

Answer: B

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PJC Answers to 2017 JC2 Prelim P2 (H2 Physics)

Suggested Solutions:

No.	Solution	Remarks
1(a)(i)	$v^2 = u^2 + 2as$ $= 2as$ $= 2(9.81)(2.000)$ $= 39.24\ \text{m}^2\ \text{s}^{-2}$ $v = 6.264\ \text{m s}^{-1}$ $\frac{\Delta v}{v} = \frac{1}{2}\frac{\Delta s}{s}$ $\Delta v = \frac{1}{2}\left(\frac{\Delta s}{s}\right)v$ $= \frac{1}{2}\left(\frac{0.001}{2.000}\right)6.264$ $= 0.002\ \text{m s}^{-1}$ $v = (6.264 \pm 0.002)\ \text{m s}^{-1}$	[1] for correct substitution and correct v [1] for correct substitution and correct Δv (no rounding off required at this stage) [1] for correct answer
1(a)(ii) 1.	$p_{\text{final}} = 0.050(0.70)(6.264)$ $= 0.22\ \text{kg ms}^{-1}$	[1] for substitution [1] for answer
1(a)(ii) 2.	Take upwards as positive $\lvert\text{average resultant force}\rvert = \frac{\lvert\Delta p\rvert}{\Delta t}$ $= \frac{0.050(0.70)(6.264) - \left[-(0.05)6.264\right]}{0.1}$ $= 5.3246\ \text{N}$ $N - mg = 5.3246$ $N = 5.3246 + 0.05(9.81)$ $= 5.82\ \text{N}$	[1] for correct resultant force [1] for correct contact force
1(b)(i)	Take upwards as positive. $s_y = u_y t + \frac{1}{2}a_y t^2$ $9.0 = (17\sin 60°)t + \frac{1}{2}(-9.81)t^2$ $t = 0.855\ \text{s}$ (rejected) or $t = 2.1468\ \text{s}$ $= 2.1\ \text{s}\ (2\ \text{s.f.})$	[1] for correct substitution [1] for correct answer

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2(a)	An ideal gas is a gas which obeys the equation of state, $PV = nRT$ for all pressure, volume and temperature.	[1]
2(b)(i)	$PV = nRT$ $n = \frac{PV}{RT}$ Since P, V and R are constant, $n \propto \frac{1}{T}$ $\frac{n_1}{n_2} = \frac{T_2}{T_1} = \frac{15 + 273.15}{38 + 273.15} = 0.926$ Fraction that must be removed = 1 – 0.926 = 0.074	[1] Correct use of equation of state to obtain $n \propto \frac{1}{T}$ [1] Correct substitution into equation to obtain ratio [1] Correct final answer
2(b)(ii)	$PV = nRT$ Since $P \propto T$, temperature doubles when pressure doubles. $\frac{1}{2}m < c^2 >= \frac{3}{2}kT$ $\sqrt{< c^2 >} = \sqrt{\frac{3kT}{m}}$ $\sqrt{< c^2 >} \propto \sqrt{T}$ $\frac{c_{rms1}}{c_{rms}} = \sqrt{\frac{T_1}{T}} = \sqrt{2} = 1.41$	[1] Temperature doubles [1] Correct final answer
2(c)	A gas is made of molecules that are constantly in random motion, colliding with each other and the walls of the container. When a molecule strikes and rebounds from a wall, it undergoes a change of momentum. According to Newton's Second Law, a force would be exerted by the wall on the molecule, to cause the change in momentum. According to Newton's Third Law, the molecules would also exert an equal but opposite force on the wall (action-reaction pair of forces). Pressure is force exerted per unit area of contact. The pressure on the walls of the container is therefore the result of the force on the walls by the molecules, as the molecules strike and rebound from the walls.	[1] Explanation using Newton's 2nd law [1] Explanation using Newton's 3rd law [1] Relate pressure to force per unit area
3(a)(i)	$\Delta x = \frac{\lambda D}{a}$ $1.7 \times 10^{-2} = \frac{\lambda (1.2)}{(0.030 \times 10^{-3})}$ $\lambda = 4.25 \times 10^{-7}$ m	[1] for correct substitution (conversion) [1] correct answer
3(a)(ii) 1.	The fringe separation will increase (by a factor of two), and the brightness will decrease, contrast will decrease.	[1] for fringe separation [1] for contrast

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3(a)(ii) 2.	In comparision, red light as a longer wavelength, therefore the fringe separation will increase, but there will be no change in brightness, hence contrast remains the same.	[1] for fringe separation [1] for contrast
3(a)(ii) 3.	The light source is initially unpolarised. With the polariser, the light that passes through will be polarised in a single plane, hence the brightness of the fringe will be lower hence contrast will decrease, no change in fringe separation.	[1] for fringe separation [1] for contrast
3(b)(i)	$d\sin\theta = n\lambda$ $\frac{1}{450\times10^{3}}\sin11.6 = (1)\lambda_{v}$ $\lambda_{v} = 4.47\times10^{-7}$ m $d\sin\theta = n\lambda$ $\frac{1}{450\times10^{3}}\sin15.8 = (1)\lambda_{r}$ $\lambda_{r} = 6.05\times10^{-7}$ m	[1] for violet light [1] for red light
3(b)(ii)	For overlap, $(n+1)\lambda_{v} \le (n)\lambda_{r}$ $n \ge 2.80$ n = 3	[1] for condition [1] for correct answer Allow trial and error method
4(a)	There is no electric field within the charged metal sphere. Since electric field strength is equal in magnitude to the electric potential gradient, the electric potential gradient will be zero between x = 0 and x = 2.0 cm, which means the electric potential is constant between x = 0 and x = 2.0 cm.	[1] [1]
4(b)	$V = \frac{Q}{4\pi\varepsilon_0 r}$ $3.6 = \frac{Q}{4\pi(8.85\times10^{-12})(2.0\times10^{-2})}$ $Q = 8.0\times10^{-12}$ C	[1] for correct substitution [1] for correct answer
4(c)	Electric potential at x = 4.0 cm due to -7.2×10^{-12} C $= \frac{-7.2\times10^{-12}}{4\pi(8.85\times10^{-12})(2.0\times10^{-2})} = -3.24$ V Electric potential at x = 4.0 cm due to charged metal sphere = 1.8 V Total electric potential at x = 4.0 cm = 1.8 – 3.24 = −1.4 V	[1] for correct electric potential due to -7.2×10^{-12} C [1] for correct substitution [1] for correct answer

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4(d)(i)	The direction of the acceleration of the particle is towards the centre of the metal sphere. The magnitude of the acceleration is larger when the particle is nearer the metal sphere.	[1] [1]
4(d)(ii)	Particle moves from x = 6.0 cm to x = 4.0 cm. Change in electric potential = 1.8 – 1.2 = 0.6 V Loss in electric potential energy = Gain in kinetic energy Kinetic energy $= (7.2\times10^{-12})(1.8-1.2)$ $= 4.32\times10^{-12}$ J $\approx 4.3\times10^{-12}$ J	[1] for correct substitution [1] for correct answer
5(a)(i)	$P = I^2R$ $7.0 = I^2(14.0)$ $I = 0.71$ A	[1] for correct use of equation [1] for correct answer
5(a)(ii)	$E = I(R+r)$ $= 0.71(14.0+3.0)$ $= 12.1$ V	[1] for correct use of equation [1] for correct answer
5(a)(iii)	$Q = IEt$ $= (0.71)(12.1)(60\times10)$ $= 5150$ J	[1] for correct use of equation [1] for correct answer
5(b)	$R = 3.0\ \Omega$	[1] for correct answer
5(c)	When R is smaller than r, a higher percentage of the power supplied by the battery is dissipated in the internal resistance. As R increases, the power dissipated in the variable resistor increases. However, the current decreases and this results in decreasing power dissipated in the variable resistor when R exceeds the value of r.	[1] for explanation of power dissipated when R is lower than r [1] for explanation of power dissipated when R is higher than r
5(d)	When $r = 0$, $P = \frac{V^2}{R}$	[1] for correct shape of graph

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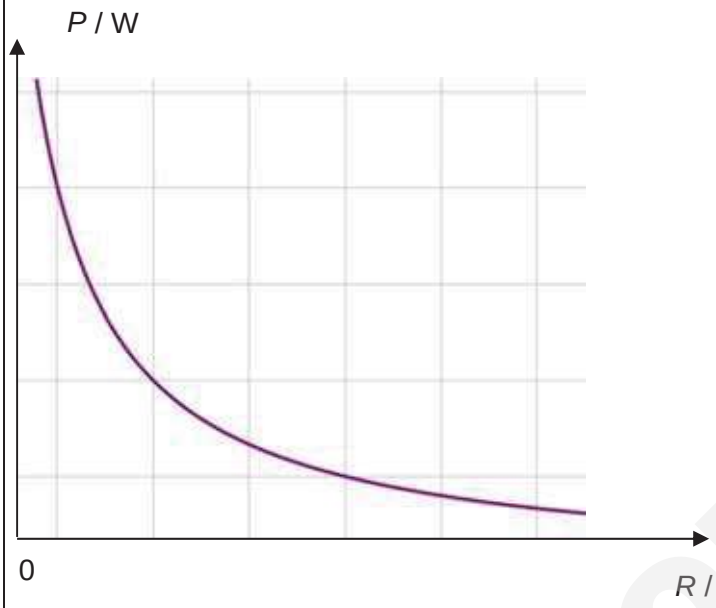
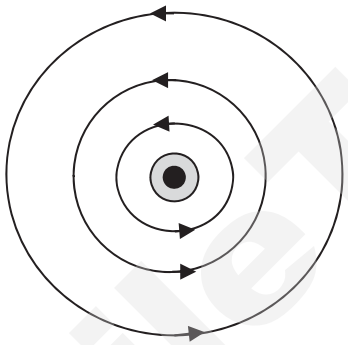
		
6(a)		[1] for series of circular field lines centered on the wire and for correct direction of arrows [1] for non-uniform field
6(b)(i)	$B = \frac{\mu_0 I}{2\pi d} = \frac{4\pi \times 10^{-7}(3.0)}{2\pi(2.0\times10^{-2})}$ $B = 3.0\times10^{-5}$ T	[1] for correct substitution
6(b)(ii) 1.	Out of the plane of the paper.	[1]
6(b)(ii) 2.	$F = Bqv\sin 90° = (3.0\times10^{-5})(1.60\times10^{-19})(1.5\times10^{7})$ $F = 7.2\times10^{-17}$ N	[1] for correct substitution [1] for correct answer
6(c)	For the flat circular coil, the magnetic flux density at the centre of the coil: $B = \frac{\mu_0 NI}{2r} = \frac{4\pi \times 10^{-7}(1)(3.0)}{2(1.3\times10^{-2})}$ Magnitude of the resultant magnetic flux density at the centre of the coil	[1] for correct substitution in $B = \frac{\mu_0 NI}{2r}$

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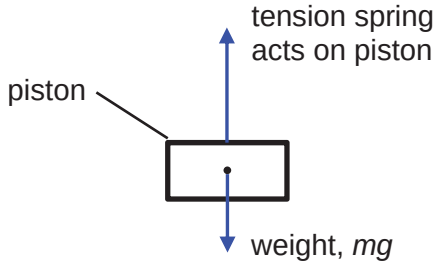
	$= \sqrt{\left[\frac{4\pi \times 10^{-7}(1)(3.0)}{2(1.3\times 10^{-2})}\right]^2 + \left(3.0\times 10^{-5}\right)^2}$ $= 1.48\times 10^{-4}$ T $\approx 1.5\times 10^{-4}$ T	[1] for correct substitution [1] for correct answer
7(a)(i)		[1] for correct forces and clear label
7(a)(ii)	Taking downwards as positive, and by Newton's second law, mg – tension $= ma$ $mg - k(x_0 + x) = ma$ (where x_0 is extension of spring at equilibrim) $-kx = ma$ (since $kx_0 = mg$) $a = -\frac{k}{m}x$	[1] for correct expression [1] for correct answer with correct sign
7(a)(iii)	Since $\frac{k}{m}$ is a constant, $a \propto -x$. This indicates that the acceleration of the piston is directly proportional to its displacement from the equilibrium position and the negative sign indicates that its acceleration is always opposite to its displacement and towards the equilibrium position. Hence, consistent with the definition of simple harmonic motion where $a = -\omega^2 x$.	[1] for $\frac{k}{m}$ being a constant [1] for correct condition for SHM
7(b)(i)	The damping of the piston is light because the oscillation of the piston continues to overshoot the equilibrium position with its amplitude decreasing by a small amount as time progresses. The period of the oscillation remains constant. For critical and heavy damping, the oscillation of the piston does not overshoot its equilibrium position.	[1] for light damping [1] for correct explanation Award no marks if no explanation
7(b)(ii)	0.85 cm to 1.00 cm	[1] for correct answer
7(c)(i)	<table><tr><td>t / s</td><td>A / cm</td><td>ln(A / cm)</td></tr><tr><td>0.37</td><td>1.40</td><td>0.336</td></tr></table>	[1] for correct answer

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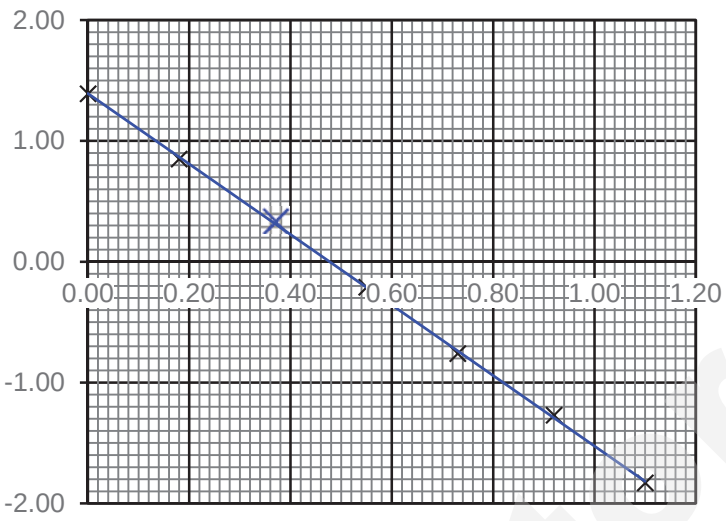
7(c)(ii) **1. & 2.**		[1] for correct plotted point for t = 0.37 s [1] for line of best fit
7(c)(iii)	Using gradient coordinates (0.10, 1.10) and (1.06, −1.70), Gradient $= \dfrac{-1.70-1.10}{1.06-0.10}$ $= \dfrac{-2.80}{0.96}$ $= -2.92$	[1] for correct gradient coordinates (read to half smallest square) and calculation [1] for correct answer
7(c)(iv)	Taking natural log of both sides, $A = A_0 e^{-2\pi f_n \gamma t}$ $\ln A = \ln A_0 - 2\pi f_n \gamma t$ $= -2\pi f_n \gamma t + \ln A_0$ The graph of ln A against t shows a straight line graph with negative gradient $-2\pi f_n \gamma$ and positive vertical intercept ln A_0. Hence, the graph in Fig. 7.6 supports the given expression.	[1] for correct linearisation [1] for correct link to the positive intercept and minus sign in the gradient
7(c)(v)	6 complete cycles take 1.10 s $f_n = \dfrac{1}{\text{period}} = \dfrac{1}{\frac{1.10}{6}} = 5.45\,\text{Hz}$	[1] for correct calculation
7(c)(vi)	Using $2\pi f_n \gamma = \lvert\text{gradient}\rvert$,	[1] for correct calculation and answer

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	$\gamma = \frac{2.92}{2\pi f_n}$ $= \frac{2.92}{2\pi(5.45)}$ $= 0.08527$ ≈ 0.0853	
7(d)	The damping coefficient is likely to be <u>higher</u> so that the vehicle suspension system <u>approaches critical damping, i.e. the piston returns to its equilibrium position in the shortest possible time</u>, hence preventing the vehicle from bouncing (oscillating) continuously after going over a hump or pothole	[1] for correct answer [1] for correct explanation Award no marks if no explanation

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PJC Answers to JC2 Preliminary Examination Paper 3 (H2 Physics)

Suggested Solutions:

1(a)	Gravitational potential energy - Energy possessed by a mass due to its position in a gravitational field Elastic potential energy - Energy stored as a result of deformation of a solid (extension and compression of an object)	[1] [1]
1(b)(i)	$F = kx$ $k =$ gradient of graph $= \frac{4.5 - 1.5}{1.8 \times 10^{-2} - 0.6 \times 10^{-2}} = 250 \text{ N m}^{-1}$	[1] for correct substitution [1] for correct answer (can accept answer if student uses one point in the graph to calculate)
1(b)(ii)	Elastic potential energy $= \frac{1}{2}Fx = \frac{1}{2}(4.5)(1.8 \times 10^{-2})$ or $\frac{1}{2}kx^2 = \frac{1}{2}(250)(1.8 \times 10^{-2})^2$ $= 0.0405 \text{ J}$ $\approx 0.041 \text{ J}$	[1] for correct substitution [1] for correct answer
1(b)(iii)	Loss in KE = Gain in EPE + Work done against friction $\frac{1}{2}(1.7)v^2 = 0.0405 + (1.2)(1.8 \times 10^{-2})$ $v \approx 0.27 \text{ m s}^{-1}$	[1] for correct equation of conservation of energy [1] for correct substitution [1] for correct answer
2(a)	Gravitational field strength at a point is defined as the gravitational force per unit mass acting at that point. Unit: N kg^{-1}.	[1] for correct definition and [1] for correct unit
2(b)(i)	gravitational force $= \frac{GMm}{R^2}$ $= \frac{6.67 \times 10^{-11}\left(5.97 \times 10^{24}\right)(1.00)}{\left(6380 \times 10^{3}\right)^2}$ $= 9.78 \text{ N}$	[1] for correct substitution [1] for correct answer

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2(b)(ii)	centripetal force $= mR\omega^2$ $= mR\left(\frac{2\pi}{T}\right)^2$ $= (1.00)\left(6380\times10^3\right)\left(\frac{4\pi^2}{\left(8.65\times10^4\right)^2}\right)$ $= 0.0337\ \text{N}$	[1] for correct substitution [1] for correct answer
2(b)(iii)	acceleration of free fall $= \frac{\text{gravitational force} - \text{centripetal force}}{\text{mass}}$ $= \frac{9.78 - 0.0337}{1.00}$ $= 9.75\ \text{m s}^{-2}$	[1] for correct substitution [1] for correct answer
2(b)(iv)	At the equator part of the acceleration due to free fall has to provide the centripetal acceleration. Hence the acceleration of free fall is lower than that at the poles. Or: Earth is not spherical. It bulges at the Equator. Distance from the poles to the centre of Earth is smaller than distance from Equator to centre of Earth. Hence the acceleration of free fall at Equator is lower than that at the poles.	[1] for correct answer
3(a)	Specific latent heat of fusion is the amount of heat (thermal energy) required to convert a unit mass of the solid, at its melting point, into liquid at the same temperature.	[2]
3(b)	Let the final temperature of water be T Heat loss by water = Heat gained by ice $m_w c_w (28 - T) = m_i l_i + m_i c_i (15 - 0) + m_i c_w (T - 0)$ $(0.2)(4.2\times10^3)(28 - T) =$ $(0.03)(3.3\times10^5) + (0.03)(2.1\times10^3)(15) + (0.03)(4.2\times10^3)T$ $23520 - 840T = 9900 + 945 + 126T$ $T = 13\ ^\circ\text{C}$	[1] Correct statement [1] Correct substitution into equation [1] Correct final answer
3(c)(i)	The first law of thermodynamics states that the increase in internal energy of a system is the sum of the heat supplied to the system and work done on the system.	[1]
3(c)(ii)	Work done on the gas, $W = -p\,\Delta V$ $= -(1.0\times10^5)(1.7\times10^{-3} - 1.5\times10^{-3})$ $= -20\ \text{J}$ By the first law of thermodynamics, the change in internal energy is given by $\Delta U = Q + W$ $= +50 + (-20)$ $= +30\ \text{J}$	[1] Correct work done and substitution into equation [1] Correct final answer

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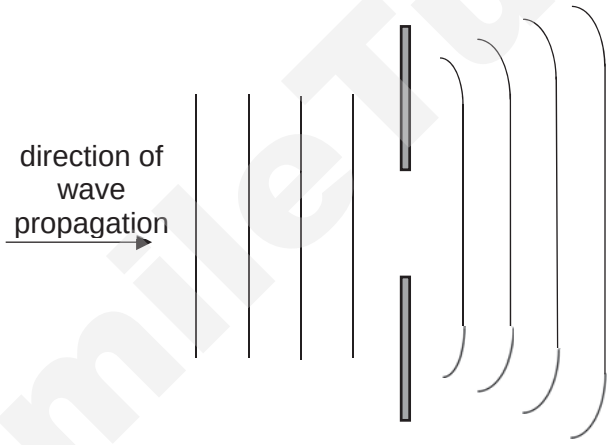
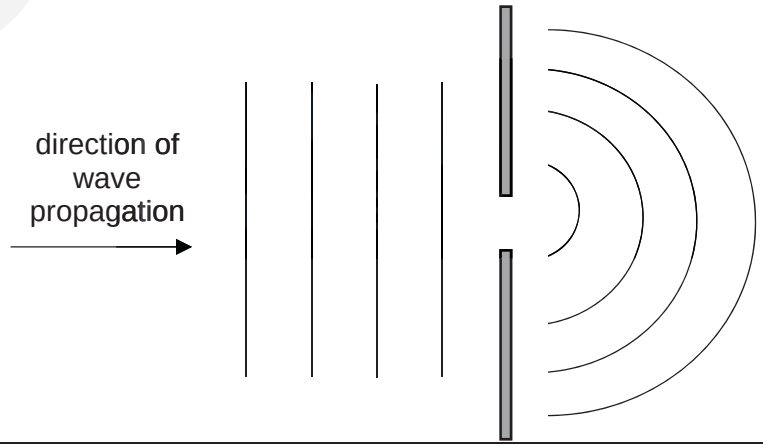
4(a)(i)	The meter reading decreases from a maximum to zero. The aerial detects microwaves that are polarised parallel to it. Hence the reading drops to zero when the plane of polarisation of the microwaves is perpendicular to the aerial.	[1] [1]
4(a)(ii)	Microwaves are transverse waves.	[1]
4(b)(i)	$\frac{A}{2} = A\cos\theta$ $\theta = 60°$	[1] for correct substitution [1] for correct answer
4(b)(ii)	$I \propto A^2$ $\frac{I_1}{(0.5A)^2} = \frac{I}{A^2}$ $I_1 = 0.25I$	[1] for correct substitution [1] for correct answer
5(a)	It is the bending of waves when it passes through an aperture or round an obstacle.	[1] [1]
5(b)(i)		[1] constant wavelength (i.e. equal spacing before and after) [1] only slight diffraction
5(b)(ii)		[1] shows greater diffraction

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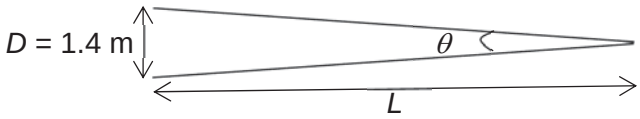
5(c)	 $\theta = \frac{\lambda}{a}$ $= \frac{500\times10^{-9}}{2.5\times10^{-3}}$ $= 2.0\times10^{-4}$ rad $\tan\theta \approx \theta$ $\frac{1.4}{L} \approx 2.0\times10^{-4}$ $L \approx 7.0\times10^{3}$ m	[1] correct use of Rayleigh criterion [1] correct answer for *L*. (Allow sin θ or $\frac{0.7}{L}$)
6(a)	$E = IR$ $= (5.25 \times 10^{-3})(63 + 750 + 480)$ $= 6.788$ V $I = \frac{E}{R} = \frac{6.788}{(750+480)} = 5.52\times10^{-3}$ A	[1] Calculating e.m.f [1] Correct final answer
6(b)(i)	Current through A_1, $I_1 = 0.50 + 0.50 = 1.0$ A $E = V + I_1 r$ $2.0 = V + 1.0\ (0.20)$ $V = 1.80$ V	[1] Correct substitution into equation [1] Correct final answer
6(b)(ii)	Connecting L_3 parallel to L_1 and L_2 will <u>lower the effective resistance of the circuit</u>. Hence, current in A_1 <u>increases</u>	[1] Correct explanation [1] Correct conclusion based on correct explanation
6(c)	P.d across AB = $\frac{0.5}{0.8}(1) = 0.625$ V $\left(\frac{3}{3+0.2+R_x}\right)2 = 0.625$ $\left(\frac{6}{3.2+X}\right) = 0.625$ $3.2 + X = 9.6$ $X = 6.4\ \Omega$	[1] p.d across AB [1] Correct substitution [1] Correct final answer

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7(a)	It is a quantum of energy of an electromagnetic radiation, and is given by *hf*, where *h* is the Planck's constant and *f* is the frequency of the radiation.	[1] [1] need to explain *h* and *f*
7(b)(i)	$$hf = \Phi + \frac{1}{2}mv^2$$ $$\frac{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)}{\left(350\times10^{-9}\right)} = 2.46\left(1.6\times10^{-19}\right) + \frac{1}{2}\left(9.11\times10^{-31}\right)v^2$$ $$v = 6.2\times10^{5}\ \text{m s}^{-1}$$	[1] photon energy [1] work function
7(b)(ii)	$$p = \frac{h}{\lambda}$$ $$mv = \frac{h}{\lambda}$$ $$\left(9.11\times10^{-31}\right)\left(6.1\times10^{5}\right) = \frac{\left(6.63\times10^{-34}\right)}{\lambda}$$ $$\lambda = 1.2\times10^{-9}\ \text{m}$$	[1] correct substitution [1] correct answer
7(c)(i)	$hf = 5.7\times10^{-19}$ J $= 3.6$ eV Since the energy of a photon is less than the work function energy, no electrons will be emitted.	[1] Evidence of photon energy less than work function energy, or equivalent [1] correct conclusion
7(c)(ii)	The energy of light is quantised where each photon transfers its energy completely to an electron. If the photon energy is lower than the work function, no electron will be emitted. Increase in intensity only increases the number of photons incident on metal per unit time.	[1] correct explanation
7(d)	When electrons transit from a higher energy level to a lower energy level, a photon corresponding to the energy level difference is emitted. Since only photons of certain energies are emitted, only transitions between certain energy levels are allowed, hence the energy levels must be discrete.	[1] [1]
8(a)(i)	As the coil leaves the region of uniform magnetic field, it experiences a changing magnetic flux linkage. According to Faraday's law, this induces an e.m.f in the coil and a current flows in the coil as it is a closed circuit.	[1] for stating changing flux linkage [1] for e.m.f. and current induced

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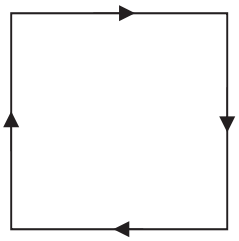
8(a)(ii)		[1] for correct current direction
8(a)(iii)	$\varepsilon = Bsv$ ..... (1) $I = \frac{\varepsilon}{R}$ ..... (2) Sub (2) into (1): $I = \frac{Bsv}{\frac{\rho 4s}{A}} = \frac{BsvA}{4\rho s} = \frac{BvA}{4\rho}$	[1] for correct induced e.m.f. expression [1] for correct current expression and substitution
8(a)(iv)	An <u>upward magnetic force</u> acts on the coil due to interaction between the induced current and magnetic field. As the coil accelerates downwards due to its weight, the induced current increases due to the <u>greater rate of change of magnetic flux through the coil</u>. Hence, the <u>magnetic force increases until it is equal to the weight of the coil</u>. Acceleration drops to zero and the coil falls with constant speed.	[1] for stating upward magnetic force on coil [1] for increasing rate of change of magnetic flux [1] for magnetic force increases until equal to weight
8(a)(v)	$F = mg$ $BIs = Vdg$ $B\left(\frac{BvA}{4\rho}\right)s = 4sAdg$ $v = \frac{4dg(4\rho)}{B^2}$ $= \frac{16(8400)(9.81)(1.5\times10^{-6})}{4}$ $= 0.49 \text{ m s}^{-1}$	[1] for equating magnetic force to weight [1] for correct substitution [1] for correct answer
8(b)(i)	The coil rotates with a constant angular frequency hence the angle between the normal of the coil and the direction of the magnetic field varies at a constant rate. This gives rise to a sinusoidal change in magnetic flux (since $\Phi = BA\cos\omega t$) and hence induced e.m.f. with time (since $\varepsilon = -\frac{d\Phi}{dt}$).	[1] for constant angular frequency [1] for sinusoidal change in flux and e.m.f.

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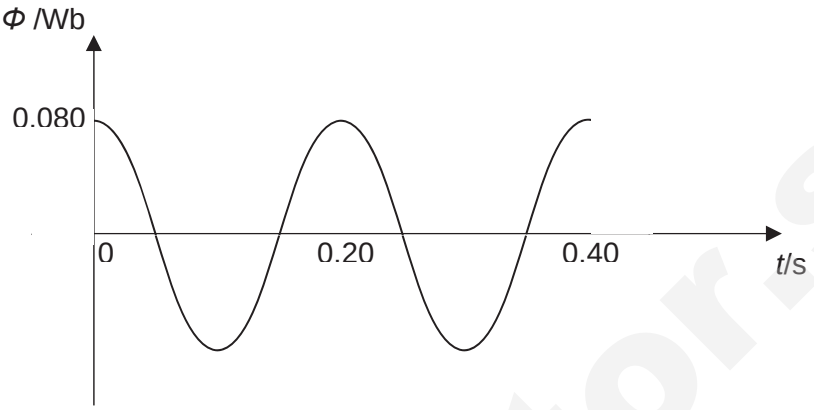
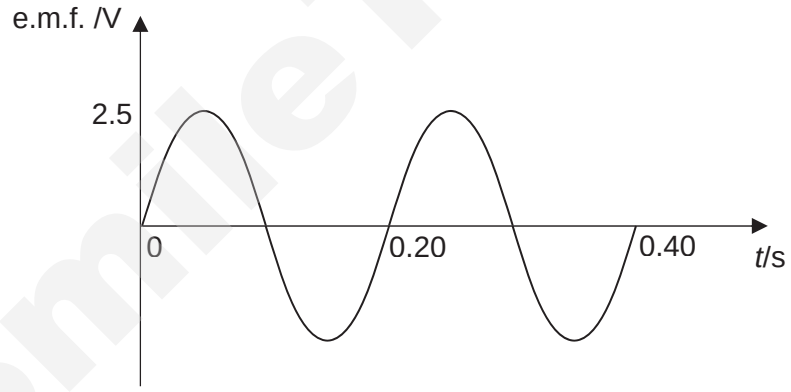
8(b)(ii)1.	$T = \frac{1}{f} = 0.20$ s $\Phi = \Phi_0 \cos \omega t = Bs^2 \cos \omega t$ $\Phi_0 = Bs^2 = (2.0)(0.20)^2 = 0.080$ Wb  	[1] for correct period [1] for correct maximum flux value [1] for correct shape
8(b)(ii)2.	$\varepsilon = -\frac{d\Phi}{dt} = Bs^2 \omega \sin \omega t$ $\varepsilon_0 = (2.0)(0.20)^2 2\pi(5) = 2.5$ V  	[1] for correct shape [1] for correct maximum e.m.f. value
8(b)(iii)	$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{\frac{\varepsilon_0}{R}}{\sqrt{2}}$ $= \frac{\varepsilon_0}{\left(\frac{4s\rho}{A}\right)\sqrt{2}}$ $= \frac{2.513}{\frac{4(0.20)(1.5\times10^{-6})}{\pi(0.00050)^2}\sqrt{2}} = 1.2$ A	[1] for correct equations [1] for correct substitution and final answer
9(a)(i)	The binding energy of a nucleus <u>is the minimum amount of energy required to break the nucleus into its constituent particles</u>.	[1] for correct explanation (or alternative)

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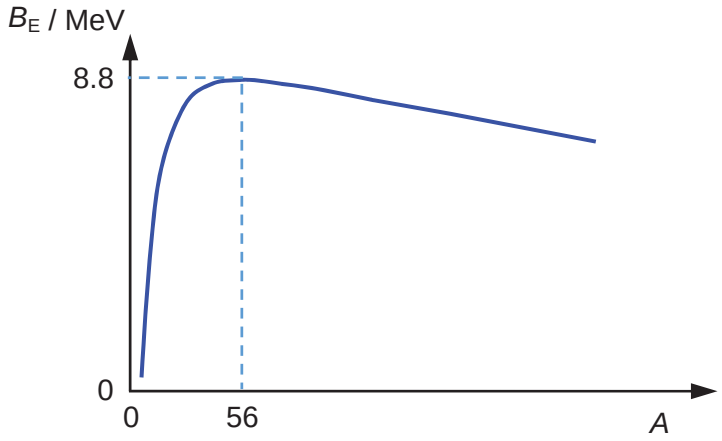
9(a)(ii)		[1] for correct shape [1] for correct values
9(a)(iii)	For nuclei having high nucleon numbers, the <u>binding energy per nucleon decreases with larger nucleon numbers</u>. When two such nuclei fuse together, they will produce a <u>daughter nucleus which has an even larger nucleon number and smaller binding energy per nucleon</u>. This means that the daughter nucleus is less stable than the parent nuclei. OR The total binding energy of the products is less than that of the initial nuclei, hence there is <u>an increase in the total mass of the system, and energy has to be supplied for such a reaction to take place</u>. No energy will be released.	[1] for correct answer [1] for correct answer
9(a)(iv)	${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$	[1] for correct answer
9(a)(v)1.	17.59 MeV of energy released $\mathrm{BE_{He}} = \mathrm{BE_{Deuterium}} + \mathrm{BE_{Tritium}} + 17.59\,\mathrm{MeV}$ $\mathrm{BE_{He}} = (2\times 1.112) + (3\times 2.827) + 17.59\,\mathrm{MeV}$ $= 28.295\,\mathrm{MeV}$ (shown)	[2] for correct answer
9(a)(v)2.	Using the definition of binding energy of a nuclei $\mathrm{BE_{He}} = \left(\sum m_{\text{constituents}} - m_{\mathrm{He}}\right)c^2$ $m_{\mathrm{He}} = \sum m_{\text{constituents}} - \dfrac{\mathrm{BE_{He}}}{c^2}$ $= (2\times 1.00728 + 2\times 1.00866)(1.66\times 10^{-27}) - \dfrac{(28.295\times 10^{6})(1.60\times 10^{-19})}{(3.00\times 10^{8})^2}$ $= 6.6426\times 10^{-27}$ $\approx 6.643\times 10^{-27}$ kg	[1] for correct mathematical definition [1] for correct expression and numerical substitution [1] for correct answer

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9(b)(i)	Spontaneous decay means the decay process is not affected by external factors such as chemical composition and physical conditions such as temperature, pressure, electric fields, magnetic fields, luminosity, etc.	[1] for correct answer
9(b)(ii)	In beta decay, there are three products – the β^--particle (electron), the daughter nucleus and the neutrino. The neutrino is a neutral particle with negligible mass in comparison with that of an electron. By the principle of conservation of energy, the total energy is shared by the daughter nucleus, the electron and the neutrino. Since there are many ways that the energy can be divided among the three particles to satisfy the conservation principle. If the electron is emitted with a large amount of energy, the neutrino is emitted with a small amount of energy and vice versa. Hence, the electrons in beta decay are emitted over a continuous range of energies.	[1] for identification of presence of neutrino [1] for principle of conservation of energy [1] for correct explanation
9(b)(iii)	Using the data of Fig. 9.2, the energy of the α-particles emitted is greater compared to that of the β^--particles. The parent nucleus bismuth-212 is less stable compared to bismuth-210, and hence more likely to undergo decay. Hence, bismuth-212 has a larger decay constant. Note: Half-life of bismuth-212 (60.6 min), decay constant (1.91×10^{-4} s^{-1}) Half-life of bismuth-210 (5.0 days), decay constant (1.60×10^{-6} s^{-1})	[1] for comparing energy of α- and β^--particles [1] for correctly identifying bismuth-212 less stable [1] for correct larger decay constant of bismuth-212
9(c)	This is because the half-life of bismuth-210 (5.0 days) is 27 times smaller than that of polonium (138 days). Therefore, the rate of decay of bismuth-210 into polonium far exceeds that of polonium to lead. In 150 days, almost all the bismuth-210 has decayed to form polonium. About half the polonium nuclei have undergone decay to form lead nuclei (1 decay).	[1] for correct comparison of half-lives [1] for correct explanation

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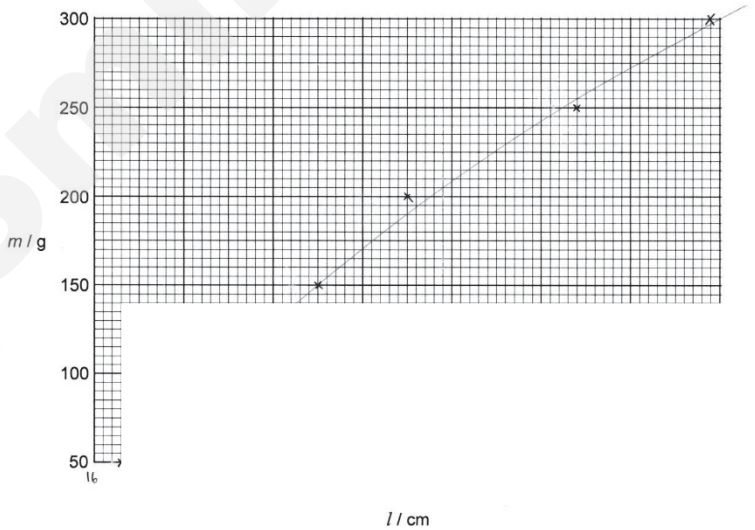
PJC 2017 JC2 Physics Preliminary Practical Examination Suggested Mark Scheme

<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td>1(b)(i)</td><td>l = 16.3 cm</td><td>[1]
- l recorded to nearest 0.1 cm
- do not accept if l is obviously too large or too small.</td></tr>
<tr><td>1(b)(ii)</td><td>$\text{percentage uncertainty} = \frac{\Delta l}{l} \times 100\%$
$= \frac{0.2}{16.3} \times 100\%$
$= 1.2\%$</td><td>[1]
- $\Delta l = 0.2$ cm (accept up to $\Delta l = 0.4$ cm)

[1]
- correct calculation
- 1 or 2 s.f.</td></tr>
<tr><td>1(c)</td><td><table><tr><th>m / g</th><th>l / cm</th></tr><tr><td>50</td><td>16.2</td></tr><tr><td>100</td><td>17.1</td></tr><tr><td>150</td><td>18.2</td></tr><tr><td>200</td><td>19.0</td></tr><tr><td>250</td><td>21.1</td></tr><tr><td>300</td><td>22.9</td></tr></table></td><td>[1]
- headings with units

[1]
- 6 sets of data with correct trend

Do not penalise for precision of readings.

Repeating and non-repeating of readings are both acceptable.</td></tr>
<tr><td>1(d)</td><td> 
</td><td>[1]
- correct plotting of points

[1]
- curve with correct shape drawn based on data points

- Do not allow straight line</td></tr>
<tr><td>1(e)</td><td>As the mass increases, the increase in extension is larger.

Spring constant decreases with increasing mass.</td><td>[1] correct identification of trend

[1] correct conclusion</td></tr>
</table>

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2(a)	$d_1 = 0.31$ mm $d_2 = 0.33$ mm $d = 0.32$ mm	[1] - d measured to the nearest 0.01 mm with consistent unit - evidence of repeated measurements of d [or in (e)] - accept $0.20 \text{ mm} \le d \le 0.40$ mm
2(c)(i)	$L = 0.990$ m	[1] - L recorded to nearest mm with consistent unit - L at least 0.900 m
2(c)(ii)	Percentage uncertainty $= \frac{\Delta L}{L} \times 100\%$ $= \frac{0.002}{0.990} \times 100\%$ $= 0.2\%$	[1] - absolute uncertainty in L is 2 mm - 6 mm - correct method of calculation to get percentage uncertainty. - percentage uncertainty expressed to 1 or 2 s.f.
2 (d)(i) and (d)(ii)	$I = 90.7$ mA $V = 1.398$ V	[1] - I recorded to the nearest 0.1 mA with consistent unit. -accept $85.0 \text{ mA} \le I \le 95.0$ mA - V recorded to the nearest 0.001 V with consistent unit. - accept $1.300 \text{ V} \le V \le 1.500$ V
2(e)	$d_1 = 0.36$ mm $d_2 = 0.38$ mm $d = 0.37$ mm	[1] - d measured to the nearest 0.01 mm with consistent unit - accept $0.30 \text{ mm} \le d \le 0.50$ mm - $d_B > d_A$
2(f)(ii)	$V = 1.038$ V	[1] - accept $0.950 \text{ V} \le V \le 1.150$ V - $V_B < V_A$ - Do not penalise d.p.
2(g)(i)	From $V = \frac{kL}{d^2}$, $k = \frac{Vd^2}{L}$	

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	For wire A: $k_A = \frac{(1.398)(0.32\times10^{-3})^2}{0.990} = 1.4\times10^{-7}$ V m For wire B: $k_B = \frac{(1.038)(0.37\times10^{-3})^2}{0.990} = 1.4\times10^{-7}$ V m	[1] Values of *k* calculated correctly [1] with correct unit.
2(g)(ii)	The values of *k* were expressed to 2 significant figures because in the calculation of *k*, the values of *d* are expressed to the least number of significant figures (i.e. 2 significant figures) compared to *L* and *V*.	[1] - Justification of s.f. linked to *L* and *d* and *V*. (must identify quantity with least s.f.)
2(g)(iii)	Percentage difference in values of *k* $= \frac{(1.446-1.435)10^{-7}}{1.435\times10^{-7}}\times100\%$ $= 0.7\%$ Since the values of k_A and k_B differ by less than 10%, they are relatively close to each other, suggesting that *k* is a constant. Hence, my experimental results support the suggested relationship $V = \frac{kL}{d^2}$.	[1] - valid conclusion based on the calculated values of *k*, using percentage difference - candidate must test against a stated criterion: the difference in the values of *k* is no more than e.g. 10%.
2(h)(i)	1. Two readings are not enough to draw a conclusion in supporting the suggested relationship. 2. Wires are kinked / not straight, hence making it difficult to measure *L* accurately. 3. It is difficult to measure the ammeter and/or voltmeter readings due to fluctuating ammeter and/or voltmeter readings with the presence of contact resistance.	[2] - Accept appropriate sources of uncertainty. - Ignore reference to parallax error, heating effects on wire and battery runs down. -Ignore non-uniform wire and take average diameter.
2(h)(ii)	1. Take more readings and plot a graph/calculate more values of *k*. 2. Suitable method to keep wire straight, e.g. hang weights off ends of wire. 3. Clean the electrical contacts before the experiment e.g. Sand-paper the crocodile clips and wire contacts, and check that the crocodile clips are tightened at the circuit contact.	[2] - 2 relevant suggested improvements. - Do not credit: take more readings and average them.
3(b)	$T = \frac{24.2+24.2}{2(30)} = 0.807$ s	[1] for repeated readings and N*T* at least 20 s.
3(c)		[2] - 6 sets of data. 1 mark for 5 sets of data.

N	*m*/g	t_1/s	t_2/s	*T*/s	lg(*m*/g)	lg(*T*/s)
30	50	24.2	24.2	0.807	1.70	−0.093
30	100	26.6	26.8	0.890	2.000	−0.051

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	40 150 36.3 35.9 0.903 2.176 −0.044 40 200 37.8 37.9 0.946 2.301 −0.024 40 250 39.7 39.6 0.991 2.398 −0.004 40 300 41.3 41.3 1.03 2.477 0.013	No marks for less than 5 sets of data. - Penalise 2 marks for no *t* values - Penalise 2 marks for wrong mode of oscillation [1] headings with units (*N* must be stated clearly or included in table) [1] *t* recorded to nearest 0.1 s (at least 4 sets more than 20 s). *m* is recorded to the nearest gram. [1] correct calculations for *T*/s, lg(*m*/g), lg(*T*/s) [1] correct s.f. for *T*/s, lg(*m*/g), lg(*T*/s)
3(d)(i)	See separate graph below	[1] - axes labelled with correct directions - correct scale [1] - correct plotting of points [1] - best fit line drawn based on student's data (penalise if best fit line is forced out)
3(d)(ii)	Use (1.980, −0.0820) and (2.310, −0.0200) $\text{gradient} = \frac{-0.0200-(-0.0820)}{2.310-1.980}$ $= 0.188$	[1] - correct substitution for gradient - gradient coordinates labelled on graph -coordinates read to half a small square accuracy [1] - correct calculation
3(d)(iii)	Use (1.980, −0.0820) $-0.0820 = (0.188)(1.980) + c$ $c = -0.454$	[1] - correct substitution for y-intercept -coordinates read to half a small square accuracy (e.c.f.) [1] - correct calculation

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3(e)	$b = 0.188$ $\lg a = -0.454$ $a = 0.352 \text{ s g}^{-0.188}$	[1] - correct *a* value - correct unit [1] - correct *b* value - correct unit
3(f)	There are two anomalous points (1.700, −0.093) and (2.000, −0.051). When the **<u>oscillating mass is small</u>**, it exhibits unintended modes of oscillations. This introduces significant counting errors and it is difficult to determine the start and stop positions of the mass accurately.	[1] - identify the anomalous points (no need to provide coordinates) [1] - correct cause for anomalies Award zero if no anomaly identified.
3(g)(i)	$T = (0.352)(1500)^{0.188}$ $= 1.39 \text{ s}$	[1] -correct calculation of *T* - allow e.c.f.
3(g)(ii)	The large value of *m* may stretch the spring beyond its elastic limit. (accept beyond proportionality limit and damaged spring)	[1] for correct problem
4	**<u>Aim</u>**: To determine the relationship between *V* and λ. **<u>Independent variable</u>**: Wavelength emitted by the LED, λ. **<u>Dependent variable</u>**: Minimum potential difference across LED, *V*. **<u>Controlled variable</u>**: - Keep distance between the LED and light detector constant.	[1] for stating wavelength, λ [1] for stating potential difference, *V* [1] for controlled variable

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Diagram:

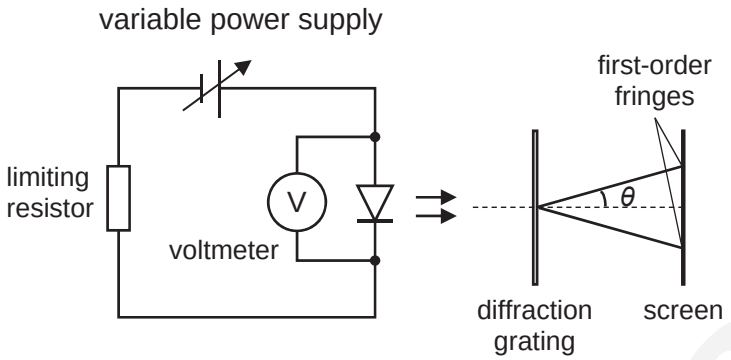

Fig. 4a

[1] for correct circuit
[1] for light sensor/probe/ detector/spectrometer

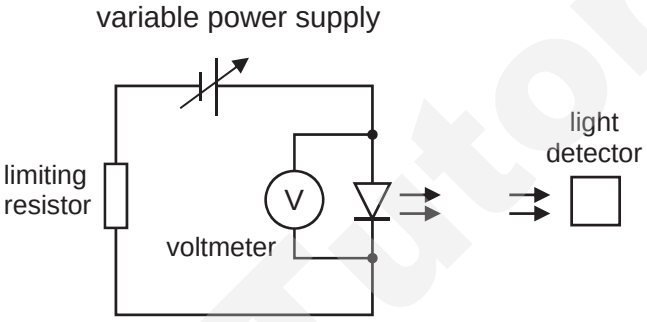

Fig. 4b

Procedure:

a. Set up the apparatus as shown above.

b. Switch on the variable power supply in Fig. 4a to obtain maximum intensity from the LED. Incident the light emitted from the LED through a diffraction grating of known grating constant *d* (distance between adjacent slits) and upon the screen.

c. Measure the angle between first-order fringe and grating normal θ using a protractor.

d. Using the diffraction grating expression $d\sin\theta = n\lambda$ to determine the wavelength λ of light emitted by LED.

e. Switch off the variable power supply and adjust power supply output to minimum.

f. Switch on the variable power supply (See Fig. 4b) and slowly increase the power supply output such that the potential difference across the LED is gradually increased until the LED (just) emits light by using the light detector. Measure and record the potential difference *V* using the voltmeter.

[1] for using methods of diffraction grating/Young's double slits/single slit to determine λ
(Accept use of LED spec chart or spectrometer to obtain λ)

[1] for method to change p.d. across LED, e.g. variable power supply / potential divider / variable resistor / rheostat
[1] for (slowly) increase the p.d. across LED until LED (just) emits light

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	g. Repeat steps (b) to (f) to obtain 6 sets of readings for V and λ using different coloured LEDs.	[1] for 6 sets. [1] for how to vary independent variables.
	h. Using the suggested relationship $V = k\lambda^n$, and linearising it to obtain $\ln V = n\ln\lambda + \ln k$, plot a graph of $\ln V$ against $\ln\lambda$, where gradient of the graph is n and vertical intercept of graph is $\ln k$	[1] for plotting a graph of of $\ln V$ against $\ln\lambda$ (Accept $\lg V$ against $\lg\lambda$)
	i. If suggested relationship $V = k\lambda^n$ is valid, the graph of $\ln V$ against $\ln\lambda$ will follow a linear trend / straight line with gradient n and vertical intercept $\ln k$.	[1] for determination of both constants (gradient and vertical intercepts). Teaching point: [relationship is valid if plotted graph is a straight line]
	<u>Further details</u>: ***Precautions to improve accuracy*:** - Take more than one reading of the potential difference V and find the average of the readings for the same λ or LED. - Carry out the experiment in a dark room or with the LED in a tube so as to minimize ambient lighting. - Readings on the voltmeter should be taken quickly so as to keep the temperature of the LED (circuit) constant. - Use a light meter / lux meter / detector (LDR) to determine the point when the LED just emits light up so as to random errors due to visual inspection by human eye. - Point the light meter / lux meter / detector (LDR) at the top of the LED as the emitted light appears to be the brightest at the top of the LED.	[1] for one appropriate precaution to improve accuracy Do not accept wire heats up
	***Safety precautions*:** - Use a protective/current-limiting resistor in the circuit set-up to prevent LEDs from burning out. - Connect the polarity of the LED correctly in the circuit to prevent LED from being damaged. - Gently wipe off any moisture or let the LED device dry before using it to prevent short-circuiting the LED. - Gently wipe off dust or dirt particles from the LED with a soft lint-free cloth before using it to prevent short-circuiting the LED.	[1] for one appropriate safety precaution Do not accept electrocution.

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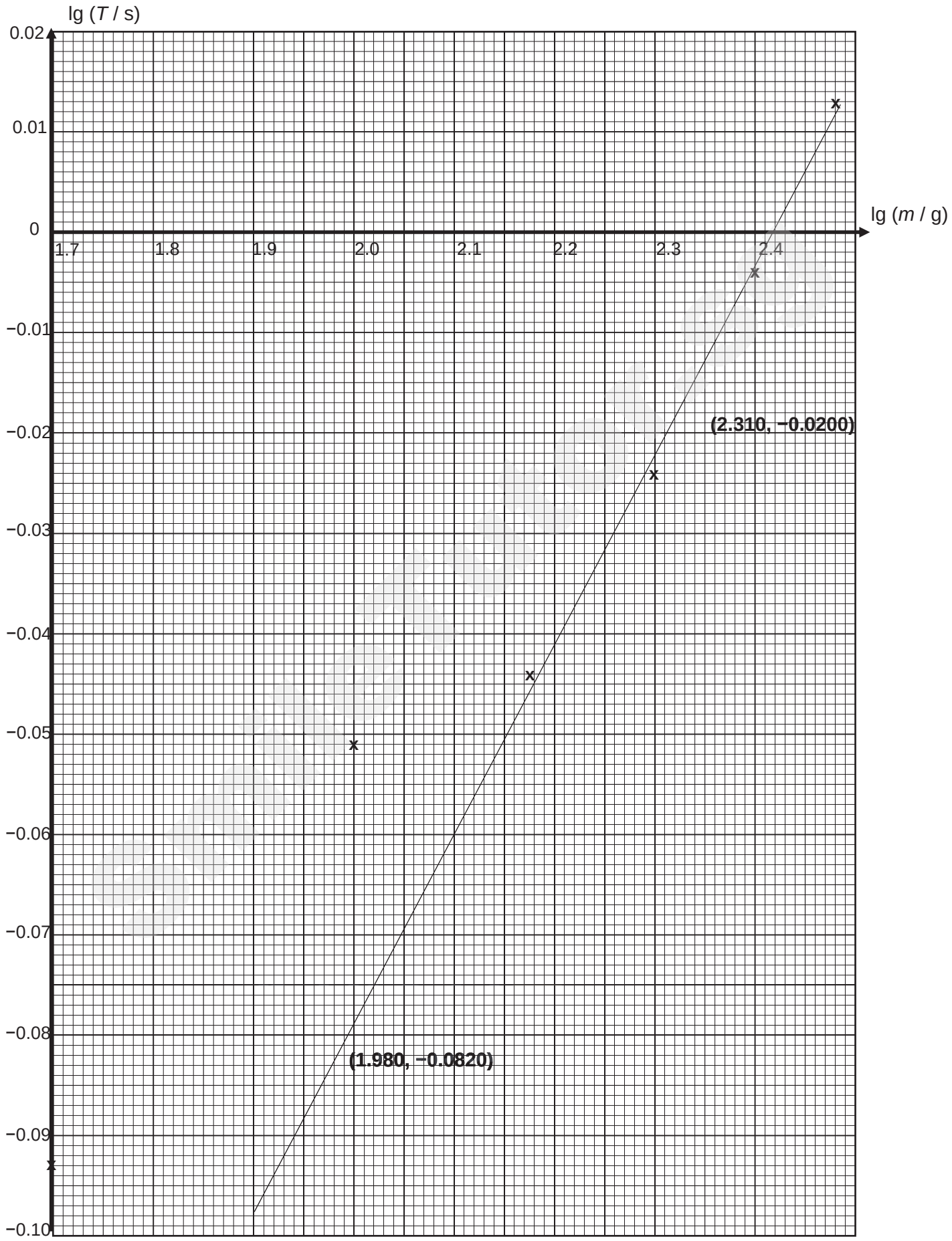

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9749 / 1
PAPER 1
22 SEPTEMBER 2017

1 HOUR

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	6								

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class above.

*There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.*

*Choose the **one** you consider correct and record your choice in **soft pencil** on the separate **Answer Sheet**.*

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done on the Question Paper.
The use of an approved scientific calculator is expected where appropriate.

The total number of marks for this paper is **30**.

This Question Paper consists of 19 printed pages and 1 blank page.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the one you consider to be correct.

1 Four students conduct their own experiments to determine the value of Planck's constant. The following table contains their experimental data.

Which student's measurement is accurate but imprecise, compared to the others?

student	Planck's constant, h / 10^{-34} J s				
A	6.64	6.61	6.61	6.64	6.65
B	6.62	6.63	6.63	6.64	6.63
C	6.63	6.68	6.61	6.68	6.65
D	6.62	6.61	6.63	6.62	6.62

2 A fireman on an aerial ladder 12.0 m above the ground is firing a stream of water at a treetop fire, as shown.



When the hose is pointed at an angle of 15.0° above the horizontal and water exits the hose at a speed of 45.0 m s^{-1}, the stream of water hits the top of a tree 34.0 m away.

What is the height of the tree?

A 6.1 m
B 18.1 m
C 85.1 m
D 97.1 m

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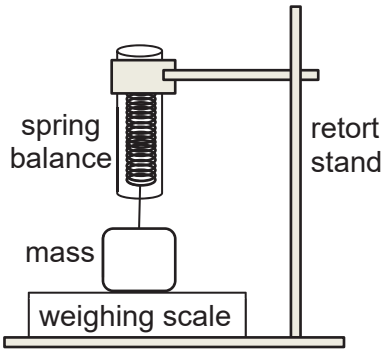
3 A mass is attached to a spring balance that is clamped firmly to a retort stand, and placed on a weighing scale, as shown.



Initially, the weighing scale reads 3.0 kg while the spring balance reads 1.0 kg. The setup is then placed in an elevator that accelerates upwards at 2.45 m s^{-2}.

What is the reading on the spring balance and the weighing scale while the elevator is accelerating?

	spring balance reading	weighing scale reading
A	0.5 kg	2.5 kg
B	1.0 kg	2.0 kg
C	1.0 kg	4.0 kg
D	1.5 kg	3.5 kg

4 A wire that obeys Hooke's law is of length x_1 when it is in equilibrium under a tension T_1; its length becomes x_2 when the tension is increased to T_2.

What is the extra energy stored in the wire as a result of this process?

A $\frac{1}{4}(T_2 + T_1)(x_2 + x_1)$
B $\frac{1}{4}(T_2 + T_1)(x_2 - x_1)$
C $\frac{1}{2}(T_2 + T_1)(x_2 + x_1)$
D $\frac{1}{2}(T_2 + T_1)(x_2 - x_1)$

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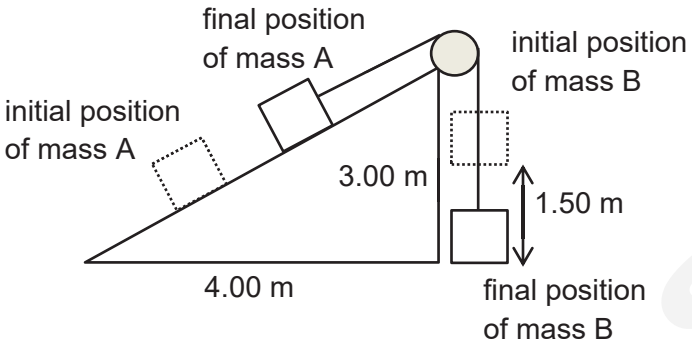
5 Two identical masses weighing 1.00 N each are attached to a pulley and placed on a ramp of height 3.00 m and width 4.00 m. They accelerate from rest until mass B has fallen 1.50 m, as shown.



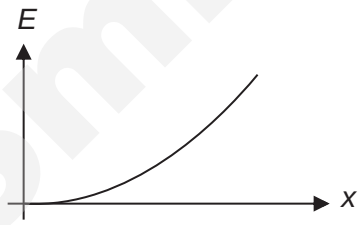
What is the change in the total gravitational potential energy of the two masses when the masses have travelled by 1.50 m?

A –0.60 J
B 0.60 J
C –0.90 J
D 0.90 J

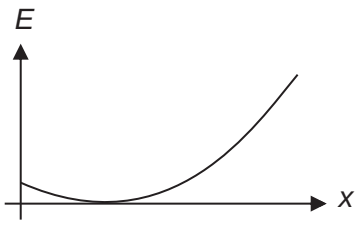
6 A mass is hung from the ceiling by a spring of unstretched length *L*. The spring is initially *compressed* with the mass at rest. The position *x* of the mass is taken to be zero at this point. The setup is then allowed to oscillate.

Which of the following graphs show how the elastic potential energy *E* varies with the position *x* of the mass for this system as it oscillates?

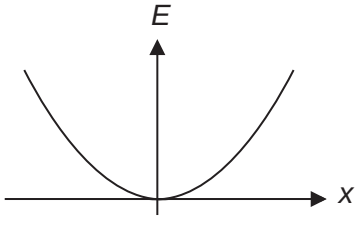
A



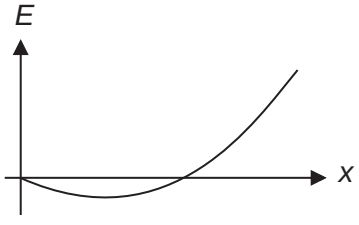
B



C



D



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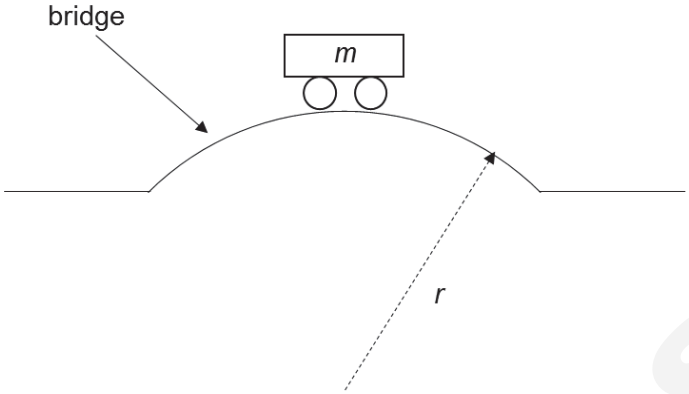
7 A car of mass m moving at a constant speed v passes over a bridge of radius of curvature r as shown.



Given that the car remains in contact with the road, what is the net force R exerted by the car on the road when it is at the top of the bridge? Take the direction of centripetal force as positive.

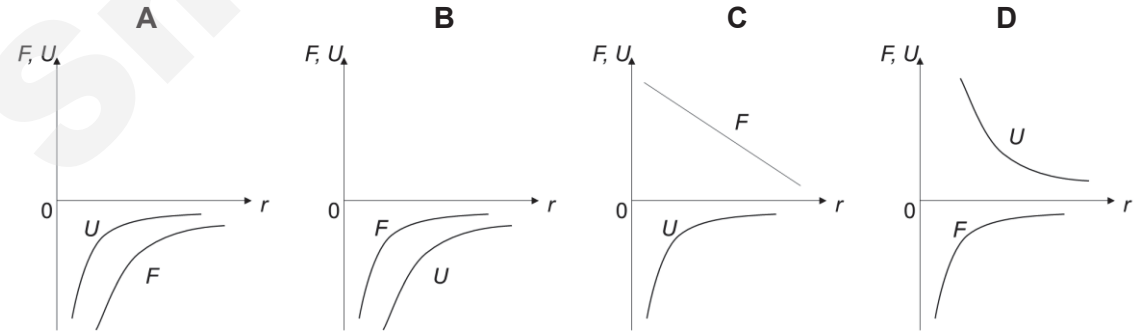
A $R = mg + \frac{mv^2}{r}$

B $R = \frac{mv^2}{r}$

C $R = mg - \frac{mv^2}{r}$

D $R = \frac{mv^2}{r} - mg$

8 Which one of the following diagrams shows the variation of gravitational force F on a point mass and gravitational potential energy U of the mass at a distance r from another point mass?



9 A planet of mass P moves in a circular orbit of radius R round a sun of mass S with period T.

Which one of the following correctly shows how T depends on P, R, S?

A $T \propto R^{\frac{3}{2}}$ **B** $T \propto R^{\frac{1}{2}}$ **C** $T \propto S^{\frac{1}{2}}$ **D** $T \propto P^2$

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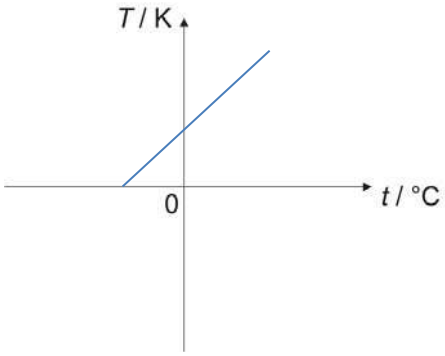
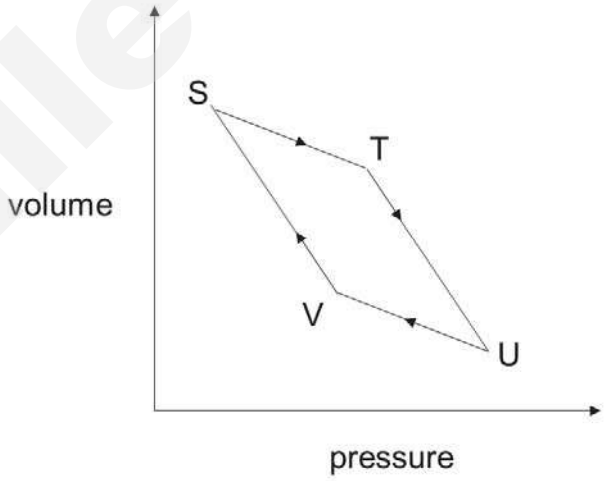
10 A student draws a linear graph on the axes shown below in order to convert temperatures in degrees Celsius to temperatures in Kelvin.



What is the gradient of the line, and intercepts on the horizontal and vertical axes?

	gradient	horizontal intercept	vertical intercept
A	1/273.15	0	–273.15
B	1	–273.15	+273.15
C	1	+273.15	–273.15
D	273.15	0	+273.15

11 A fixed mass of gas undergoes the cycle of changes represented by STUVS as shown. In some of the changes, work is done *on* the gas and, in others, work is done *by* the gas.



In which pair of the changes is work done *on* the gas?

A ST and TU
B TU and UV
C UV and VS
D VS and ST

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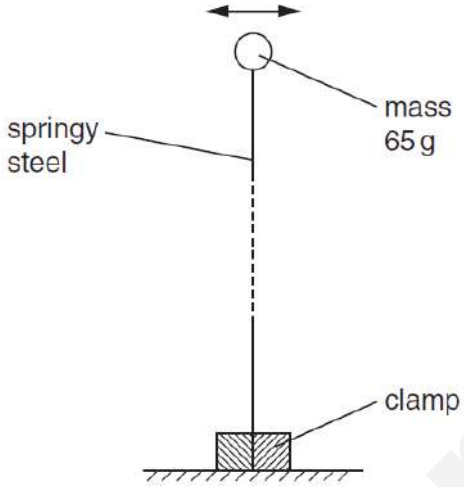
12 A long strip of springy steel is clamped at one end so that the strip is vertical. A mass of 65 g is attached to the free end of the strip as shown.



The mass is pulled to one side and then released. The variation with time t of the horizontal displacement of the mass is shown below.

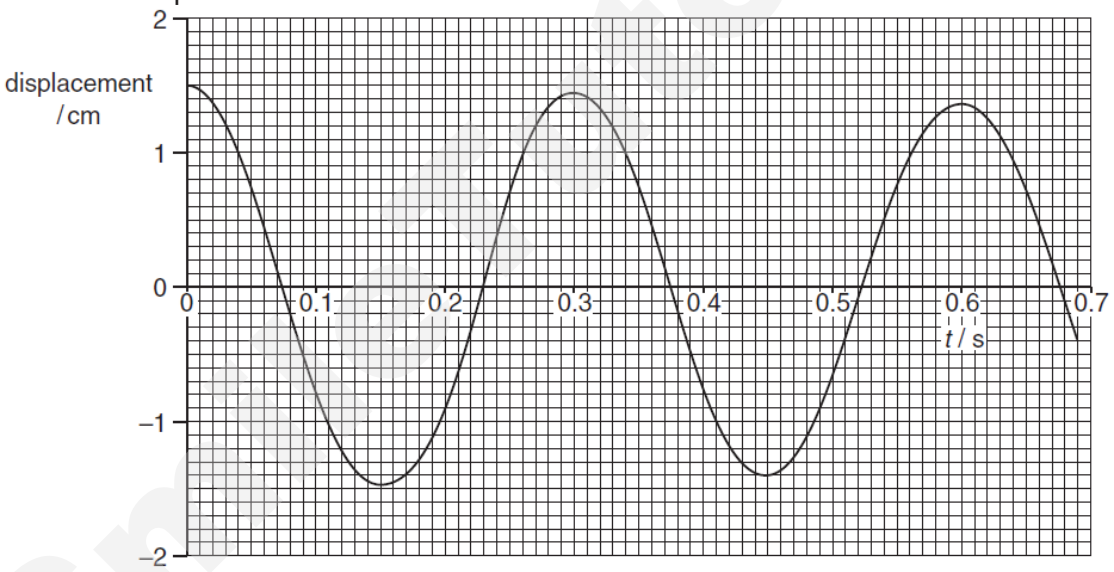


Fig. 11.2

Which of the following statements is incorrect?

A If the 65 g mass is changed to a 80 g mass, the period will be longer than 0.3 s.

B Maximum acceleration occurs at t = 0 s and decreases gradually with each cycle.

C Maximum velocity occurs at t = 0 s and decreases gradually with each cycle.

D The oscillations are lightly damped.

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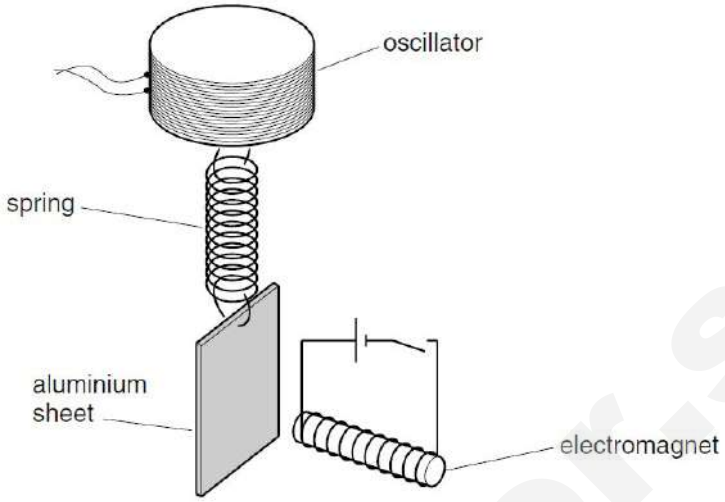
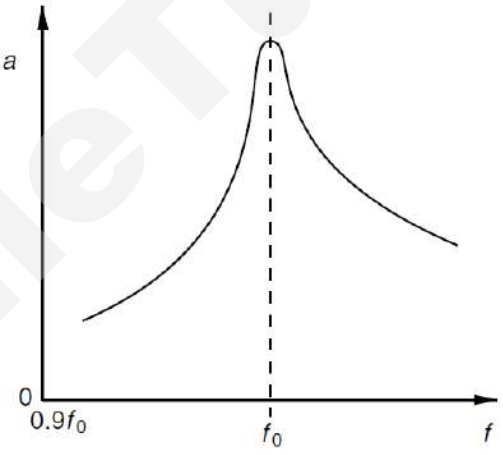
13 An aluminium sheet is suspended from an oscillator by means of a spring, as illustrated.



An electromagnet is placed a short distance from the centre of the aluminium sheet.

The electromagnet is switched off and the frequency f of oscillation of the oscillator is gradually increased from a low value. The variation with frequency f of the amplitude a of vibration of the sheet is shown below.



The electromagnet is now switched on and the frequency of the oscillator is again gradually increased from a low value.

Which is the variation with oscillator frequency f of the amplitude a of vibration of the sheet (dotted line)?

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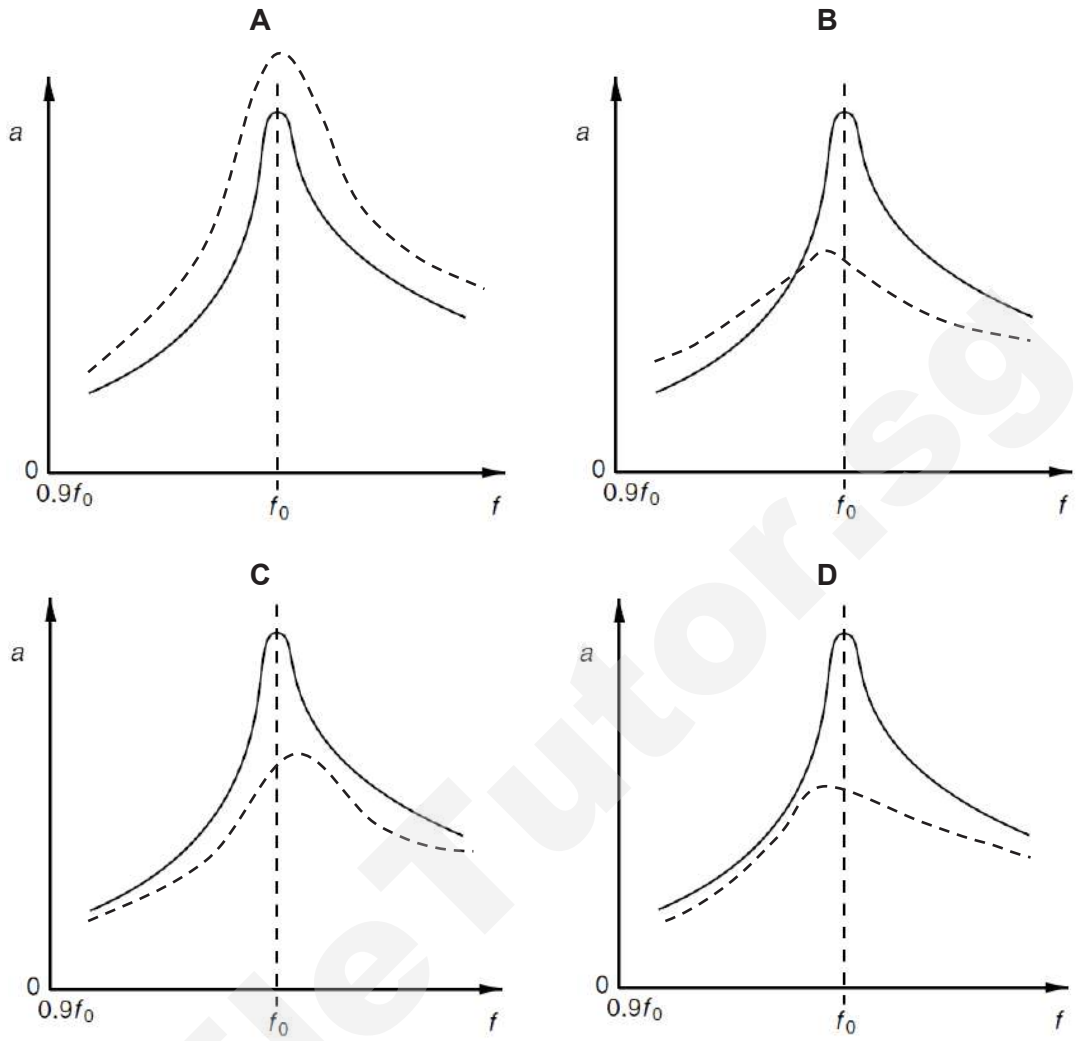

14 Fig. A shows the displacement y against position x of a progressive wave at time $t = 0$ and Fig. B shows the displacement y against time t of the same wave at position $x = 0$.

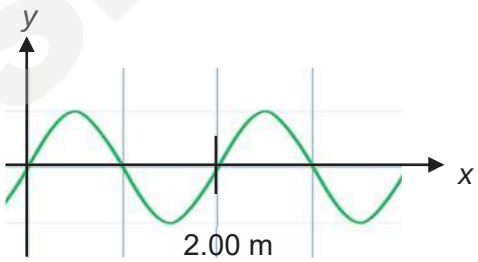

Fig. A

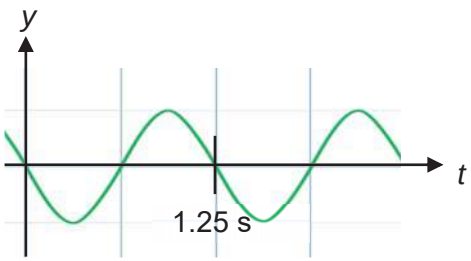

Fig. B

What is the speed and direction of the wave's propagation?

A 1.60 m s^{-1} to the right
B 1.60 m s^{-1} to the left
C 2.50 m s^{-1} to the right
D 2.50 m s^{-1} to the left

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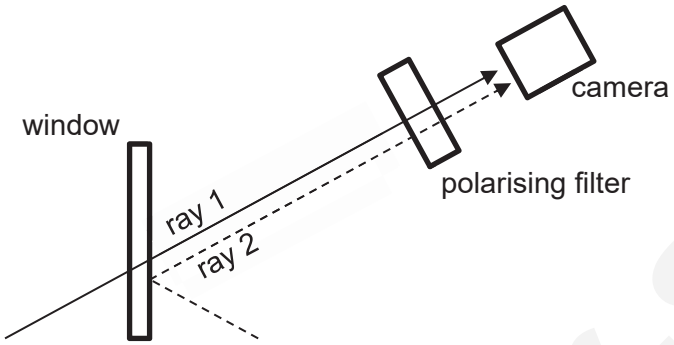
15 Light reflecting off a glass surface (ray 2) becomes polarised, while light passing through the glass surface from the other side (ray 1) is unpolarised. A photographer reduced the intensity of reflected light reaching the camera by placing a polarising filter in front of the camera, as shown.

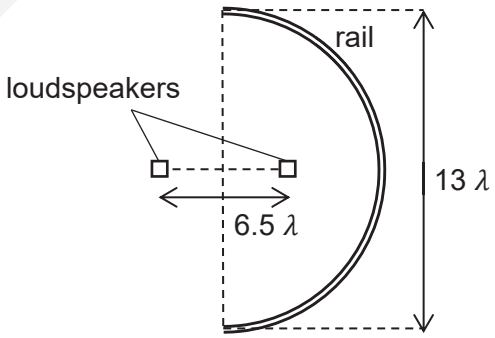


She found that when the intensity of ray 2 was at a maximum, it was equal to that of ray 1 reaching the camera. She then rotated the filter 70° from that position.

What is the ratio of the intensity at the camera of ray 2 to ray 1 in this new position?

A 0.12
B 0.34
C 0.88
D 0.93

16 Two loudspeakers are emitting sound of wavelength λ in all directions. They are in phase with each other and are placed a distance 6.5 λ apart in the middle of a semicircular rail of diameter 13 λ, as shown below. Moveable microphones along the rail are used to detect the sound intensity along the rail.



How many minima will the microphones detect?

A 11 **B** 12 **C** 13 **D** 14

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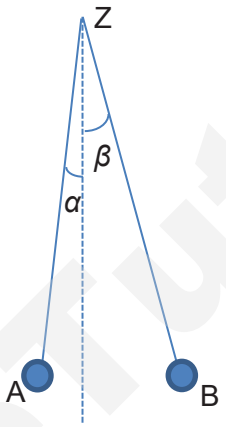
17 Which of the following statements about an electric field is correct?

A If the electric field strength at a given point is zero, there is no charge in the vicinity of that point.
B If the electric field strength inside a solid conducting sphere is constant, the electric potential inside the sphere is zero.
C If the electric potential at a given point is zero, there is no charge in the vicinity of that point.
D If the electric potential inside a solid conducting sphere is constant, the electric field strength inside the sphere is zero.

18 The diagram shows two light charged spheres, A and B, which are hung by identical fine nylon threads from a fixed point Z. It is found that, in equilibrium, the angle β is greater than the angle α.



Which one of the following statements must be correct?

A The force of repulsion on A is numerically smaller than that on B.
B The charge on A is numerically smaller than that on B.
C The mass of A is numerically greater than that of B.
D The tension of string holding A is smaller than that of B.

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19 Fig. A, B and C show three different circuits.

The cells in each circuit have the same electromotive force and zero internal resistance. The five resistors each have the same resistance R.

In Fig. A, the power dissipated in the resistor is P.

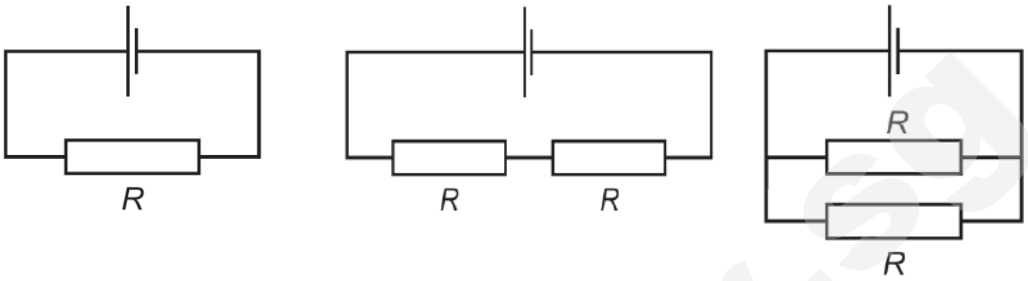


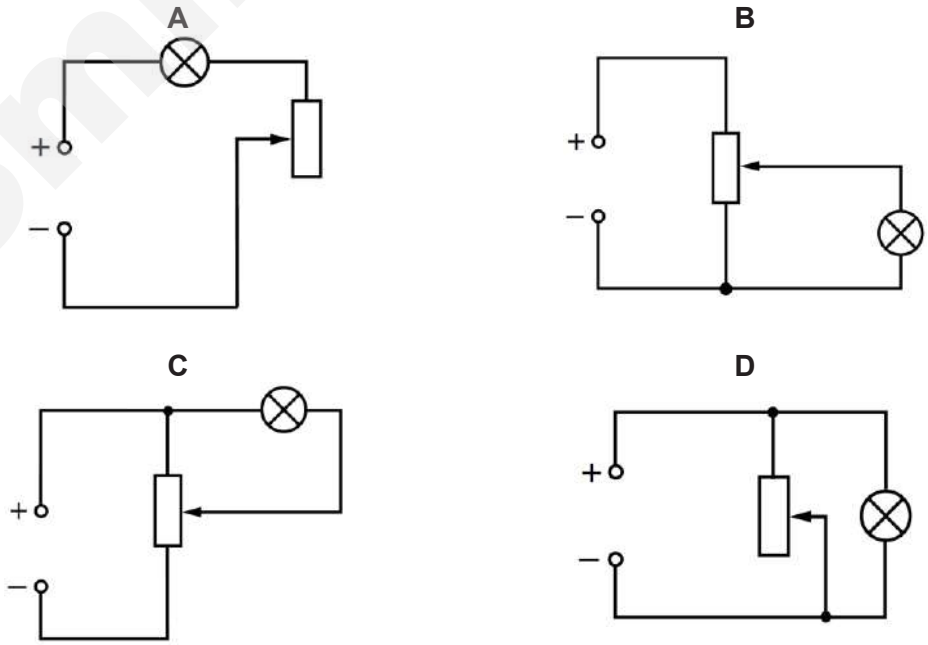
Fig. A **Fig. B** **Fig. C**

Which of the following statements is incorrect?

A In Fig. B, the power dissipated in the circuit is $\frac{1}{2}P$.
B In Fig. C, the power dissipated in the circuit is $8P$.
C The power dissipated in the circuit of Fig. C is quadrupled the power dissipated in the circuit of Fig. B.
D The total current through the cell in Fig. C is larger than the total current through the cell in Fig. B.

20 A lamp is connected to a power supply of negligible internal resistance.

Which circuit could not be used as a practical means to vary the voltage across the lamp?



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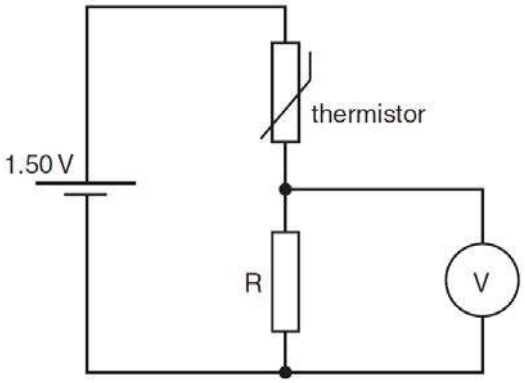
21 A thermistor has resistance 3900 Ω at 0 °C and resistance 1250 Ω at 30 °C. The thermistor is connected into the circuit shown below in order to monitor temperature changes.



The battery of e.m.f. 1.50 V has negligible internal resistance and the voltmeter has infinite resistance.

If the voltmeter reading is 1.00 V at 0 °C, what will be the voltmeter reading at 30 °C?

A 0.16 V
B 0.21 V
C 0.32 V
D 1.3 V

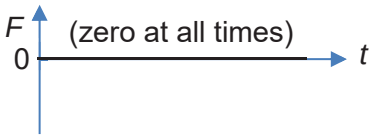
22 Two parallel conductors carry equal sinusoidal alternating currents differing in phase by π rad.

Which one of the following graphs shows how *F*, the mutual force of attraction, varies with time *t*?

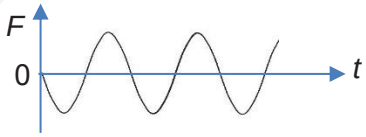
A



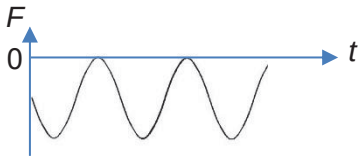
B



C



D



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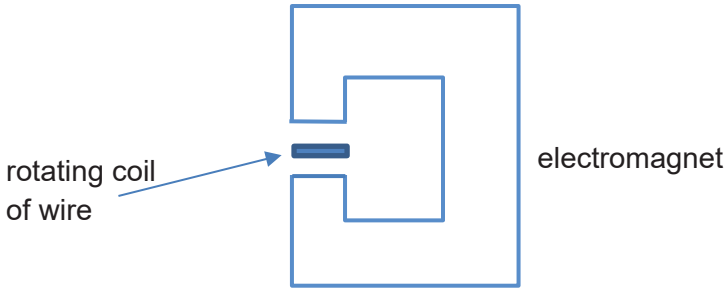
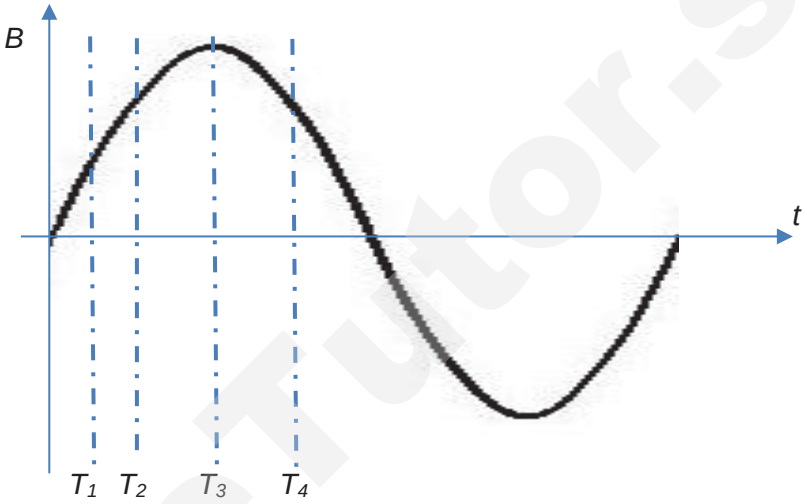
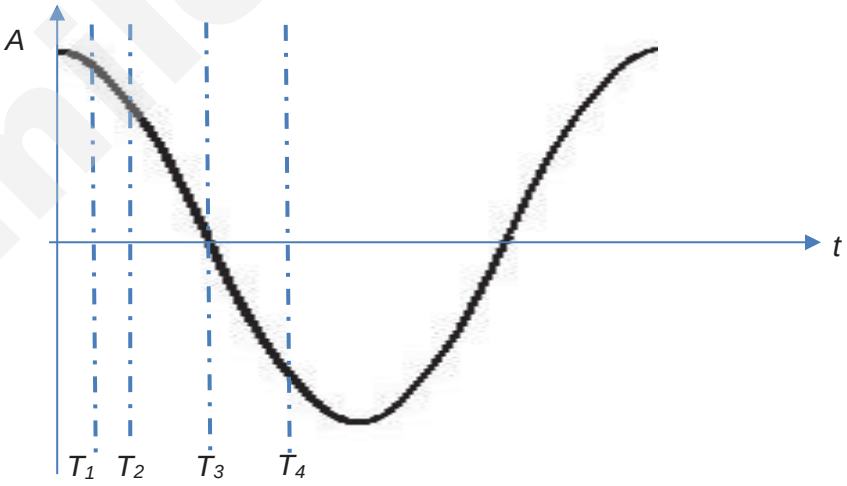
23 An e.m.f is induced in a rotating wire subjected to a changing magnetic field of an electromagnet.



The flux density B of this field varies with time t as shown.



The plane area A normal to the field varies with time t as shown.



At which value of time t is the magnitude of the e.m.f. induced in the wire a maximum?

A T_1
B T_2
C T_3
D T_4

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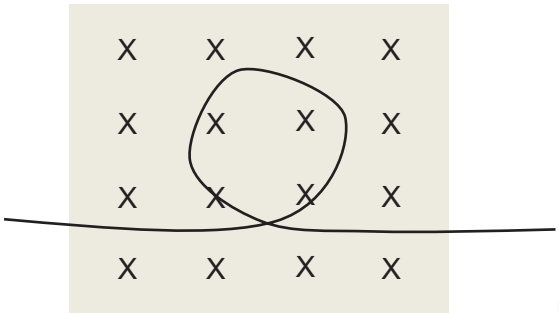
24 A wire is coiled once with an enclosed area of 0.140 m^2. It is placed with its axis parallel to a uniform magnetic field. The flux density of the field is constant at 80 mT. The two ends of the wire are pulled such that the area of the coil is decreased to 0.070 m^2 over a period of 2.0 s.



What is the average magnitude and direction of the induced e.m.f.?

A 2.8 mV, clockwise
B 5.6 mV, clockwise
C 2.8 mV, anticlockwise
D 5.6 mV, anticlockwise

25 Gas molecules are placed inside a sealed box with a loudspeaker. They are made to vibrate with a speed $v = v_0 \sin \omega t$ where $v_0 = 3.00$ m s^{-1} and $\omega = 600$ rad s^{-1}.

What is the root-mean-square speed v_{rms} of the gas molecules?

A 1.50 m s^{-1}
B 2.12 m s^{-1}
C 3.00 m s^{-1}
D 4.24 m s^{-1}

26 A diode and a resistor are connected in series with an a.c. power supply. This power supply provides an a.c. voltage at 220 V with a frequency of 50 Hz.

What percentage of the average power provided by the source is dissipated across the resistor?

A 0%
B 25%
C 50%
D 71%

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27 When fireworks detonate, the thermal energy excites electrons in the shells of metal ions. Characteristic energy transitions of several compounds are given below.

compound	energy transitions / eV
strontium chloride	1.89
barium chloride	2.43
copper chloride	2.87
zinc monoxide	8.73
aluminium nitride	9.83

Given that aluminium nitride emits light in the ultraviolet range when this energy transition occurs, which of the following is most likely to be the compound used in a yellowish-green firework?

A strontium chloride
B barium chloride
C copper chloride
D zinc monoxide

28 Protactinium-234 undergoes beta decay into uranium-234. In this process, it emits beta particles with energies up to 2.27×10^6 eV as well as gamma rays with energies up to 1.97×10^6 eV.

A sample of protactinium-234 is placed in a thick metal box, which blocks beta decay from leaving the box. A detector placed outside the box found gamma rays emanating from the box.

What is the smallest wavelength of gamma ray observed?

A 5.48×10^{-13} m
B 6.31×10^{-13} m
C 8.76×10^{-32} m
D 8.24×10^{-31} m

29 Data for the masses of some particles and nuclei are given below:

	mass / u
proton	1.0073
neutron	1.0087
deuterium (^2_1H)	2.0141

What is the binding energy of deuterium?

A 4.54×10^{-32} eV
B 2.84×10^{-12} J
C 1.77 MeV
D 27.4 MeV

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30 One possible fission reaction of uranium-235 is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n .$$

The binding energy per nucleon of each nucleus is as follows.

$^{235}_{92}U$: 1.2191 × 10^{-12} J

$^{144}_{56}Ba$: 1.3341 × 10^{-12} J

$^{90}_{36}Kr$: 1.3864 × 10^{-12} J

What is the mass equivalence of the energy released in this reaction?

A 1.67 × 10^{-29} kg
B 1.38 × 10^{-28} kg
C 3.38 × 10^{-28} kg
D 1.01 × 10^{-19} kg

END OF PAPER

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9749 / 2
PAPER 2
11 SEPTEMBER 2017

2 HOURS

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	6								

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected where appropriate.

Candidates answer on the Question Paper.
No Additional Materials are required.

*Answer **all** questions*.

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE	
Paper 1	**/ 30**
Paper 2	
1	**/ 10**
2	**/ 5**
3	**/ 10**
4	**/ 10**
5	**/ 10**
6	**/ 10**
7	**/ 5**
8	**/ 20**
Deduction	
Paper 2	**/ 80**

This document consists of **20** printed pages.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 (a) (i) Distinguish between *random* and *systematic error*.

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……

……

……

……

……

……

…… [3]

(ii) Suggest a method to reduce the effect of random error in an experiment.

……

……

…… [1]

(b) A ball approaches a ramp with an inclination of 30°. It hits the surface of the ramp at a speed of 5.0 m s^{-1} at 45° to the normal and bounces off with a speed of 5.0 m s^{-1} as shown in Fig. 1.1.

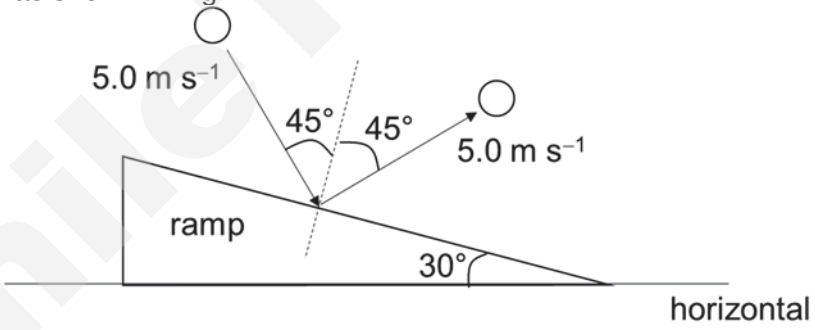

Fig. 1.1

Determine the change in velocity of the ball.

magnitude of change in velocity = …… m s^{-1} [2]

direction of change in velocity is …… °
with respect to the horizontal [2]

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(c) The behaviour of many real gases deviates from the ideal gas equation $pV_m = RT$, where V_m refers to molar volume while the other symbols have their usual meaning. Its behaviour can instead be represented quite closely over certain ranges of temperature and pressure by an equation of the form

$$\left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

in which the values of a and b are characteristic of the particular gas.

Determine the base S.I. units of a and b.

units of a = ……

units of b = …… [2]

2 **(a)** A stone is thrown with an initial velocity v at an angle θ above the horizontal. Assume air resistance to be negligible.

Assuming that the stone returns to the same vertical height, show that the range d (horizontal distance) that it can reach is given by the expression

$$d = \frac{v^2 \sin 2\theta}{g}$$

[3]

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(b) Hence or otherwise, show that the maximum range, given that it returns to the same vertical height, is obtained at the angle of 45°.

[1]

(c) Fig. 2.1 shows the path of the projectile motion when the angle of launch is 45°.

On Fig. 2.1, draw possible path(s) of the projectile motion of the stone that can reach point X with the same initial speed.

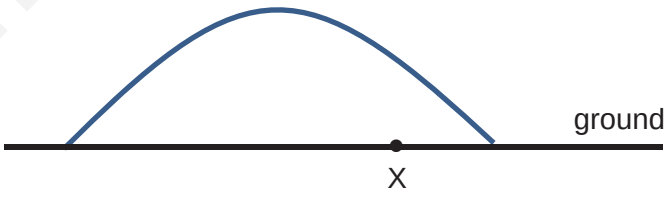

Fig. 2.1

[1]

3 **(a)** Define *density* and *pressure*.

……

……

……

…… [2]

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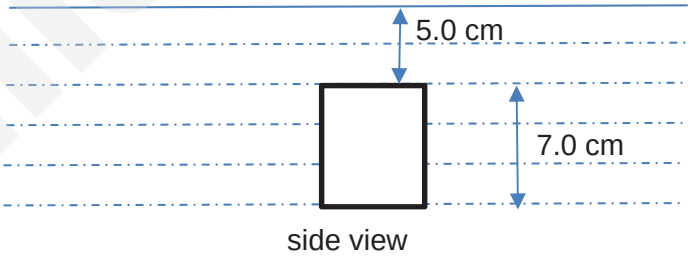
(b) Using the definitions which you have given in **(a)**, derive an expression for the upthrust experienced by an object in a fluid in terms of the fluid density ρ and the volume V of the object.

[3]

(c) A rectangular block of wood of cross-sectional area 10 cm^2 and thickness 7.0 cm is held at a depth of 5.0 cm in water as shown in Fig. 3.1. and Fig. 3.2.

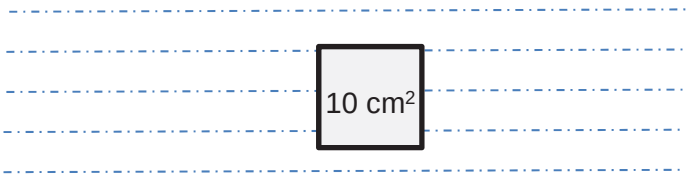
It is subsequently released, and the block moves upwards and leaves the surface of the water completely.

Density of water = 1000 kg m^{-3}
Density of wood = 430 kg m^{-3}



side view

Fig. 3.1



bottom view

Fig. 3.2

(i) On Fig. 3.1. draw and label the forces acting on the block at its initial position, just after its release.

[1]

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(ii) Calculate the resultant force of the block just after its release.

resultant force = …… N [1]

(iii) Calculate the time taken for the top surface of the block to just reach the surface of water after its release.

time taken = …… s [2]

(iv) Without making further calculations, sketch a graph showing the variation with time of the resultant force acting on the block from time of release to just before it completely leaves the surface of water.

[1]

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4 A smooth sphere of mass m is held horizontally between two fixed points A and B by two identical stretched helical springs, each of spring constant k, as shown in Fig. 4.1.

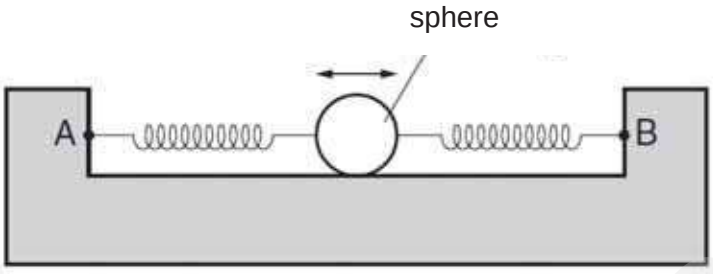

Fig. 4.1

When the sphere is in equilibrium, the extension of each spring is e.

The sphere is then displaced a small distance x to the right along the axis of the springs.

Both springs remain extended.

(a) (i) Show that the resultant force F acting on the sphere is given by

$$F = -2kx.$$

[2]

(ii) Hence, explain why, after releasing the sphere from rest, the subsequent motion is simple harmonic.

……

……

……

…… [2]

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(b) **(i)** The mass m of the sphere is 37 g and the spring constant k is 9.0 N m^{-1}.

Determine the angular frequency of oscillation of the sphere.

angular frequency = ... rad s^{-1} [2]

(ii) Given that x = 2.8 cm, show that the total energy of the oscillations is 7.0 mJ.

[2]

(iii) Calculate the magnitude of the displacement at which the kinetic energy of the sphere is equal to the total potential energy stored in the springs.

displacement = ... m [2]

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5 **(a)** A point source emits radio waves with a frequency of 30 kHz in all directions. These radio waves are incident on an antenna 5.0 km away, and can take two possible paths to reach the antenna. Path A is the direct path from source to antenna, while Path B is reflected off the ground, as shown in Fig. 5.1.

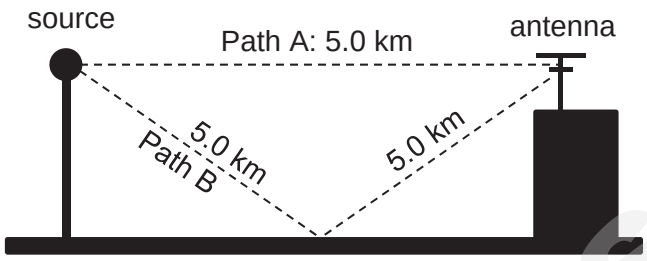

Fig. 5.1

(i) Show that there is a phase difference of π between the oscillations at the source and the oscillations at the antenna for a wave that is travelling along path A.

[2]

(ii) When the radio wave reflects off the ground for Path B, it undergoes a phase change of π.

Determine whether the waves travelling along Path A and Path B undergo constructive or destructive interference at the antenna.

[2]

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(b) Instead of emitting radio waves in all directions, radio waves may instead be channelled through a hollow metal tube of constant cross-sectional area. The waves are confined within the tube because they bounce off the metal surfaces.

(i) Explain why this is considered to be a more efficient method of transmitting electromagnetic waves than emitting in all directions.

……

……

……

…… [2]

(ii) It is observed that standing waves may develop inside the metal tube. Explain how these standing waves form.

……

……

……

…… [2]

(c) Different radio channels use different wavelengths of radio waves to transmit signals. For example, MediaCorp's Gold 90.5 uses radio waves with a frequency of 90.5 MHz, while Channel U is broadcasted at 579 MHz.

A resident of Pulau Ubin discovered that when he was behind the hills, he was unable to receive reception of Channel U. However, he was still able to listen to Gold 90.5. Suggest why this phenomenon occurs.

……

……

……

…… [2]

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6 A copper cable, of length 0.24 m and diameter 2.4 mm, connects a car's battery to its starter motor. The copper cable carries a current of 150 A and the voltage drop across the cable is 0.13 V.

(a) **(i)** Calculate the resistance of the copper cable.

resistance = …… Ω [2]

(ii) Hence, or otherwise, calculate the resistivity of copper.

resistivity = …… Ω m [3]

(b) **(i)** Given that the number of electrons in the copper cable is 1.6×10^{18}, determine the drift velocity of the electrons in the copper cable.

drift velocity = …… m s^{-1} [3]

(ii) Without any calculations, state and explain the change, if any, to the drift velocity if the same current now flows through another copper cable of which diameter is doubled.

……

……

……

…… [2]

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7 A power station generates 1.0 MW of power and the generated voltage of an alternating current (a.c.) is stepped up to 300 kV by a transformer for transmission as shown in Fig 7.1.

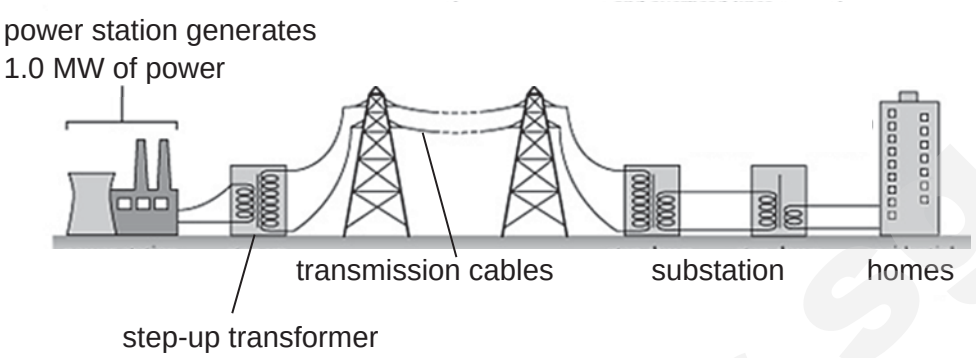

Fig. 7.1

The transmission cables of length 10 km have a total resistance of 8.0 kΩ. At an electrical substation near homes, the voltage is stepped down in various stages to a standard 240 V a.c. power supply for homes.

(a) Calculate the power lost via the transmission cables, and state any assumptions made in your calculations.

power loss = …… kW [2]

(b) A man decides to use a step-down transformer to step down the 240 V a.c. voltage, and then convert it to direct current (d.c.) using a single diode for an electrical appliance which requires 12 V d.c.

Determine the turns ratio N_P/N_S required for the step-down transformer to provide an equivalent d.c. voltage of 12 V.

turns ratio = …… [3]

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8 In a photoelectric experiment, a student uses a mercury vapour lamp with filters as a source of light. After applying the filters, the light source consists only of two wavelengths, one of 405 nm and the other of an unknown ultraviolet (UV) wavelength.

The set up is shown in Fig. 8.1 with the sodium metal placed in an evacuated tube and connected to a circuit as electrode B. The sodium metal has a work function of 2.3 eV. A sensitive micro-ammeter and voltmeter are connected to the main circuit with the electrodes to measure values of current and potential difference across the electrodes as the e.m.f. source is varied. When the potential difference between A and B (ΔV) is positive, a constant photoelectric current is detected in the ammeter.

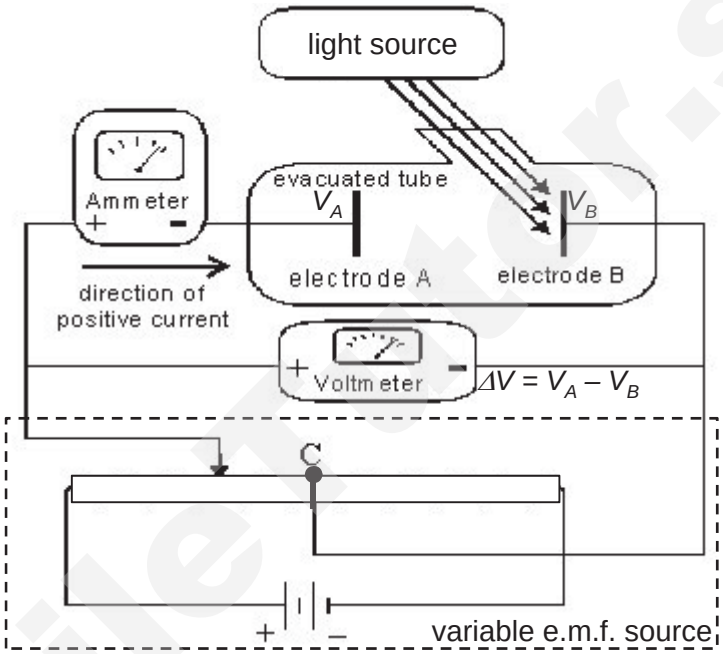

Fig. 8.1

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(a) The student varies the potential difference across the electrodes and obtains a relationship between the total detected photoelectric current and the potential difference ΔV as shown in Fig. 8.2.

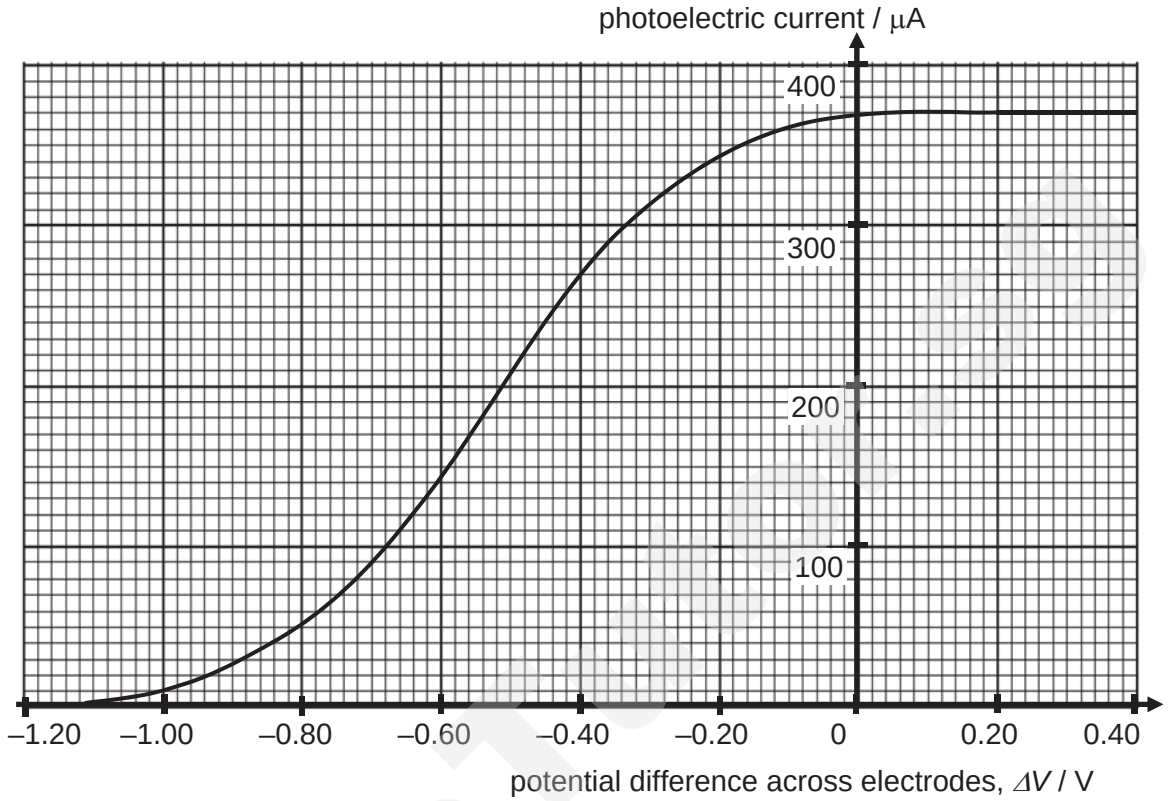

Fig. 8.2

(i) Using Fig. 8.2, describe how the total detected photoelectric current varies with the potential difference across electrodes A and B.

……

……

…… [2]

(ii) Using Fig. 8.2, determine the stopping potential V_S which stops the most energetic photoelectrons from reaching electrode A.

stopping potential V_S = …… V [1]

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(iii) Hence, calculate the wavelength of the UV light.

wavelength = …… m [2]

(iv) Show that if the source is monochromatic and only emits light of wavelength 405 nm, the stopping potential would be 0.77 V.

[1]

(v) Assume that for both wavelengths emitted by the lamp, the emitted photons are incident on the metal with the same intensity, and the ratio of photons absorbed to photoelectrons emitted is 1.

Calculate the total power of light incident on the metal due to both wavelengths.

power = …… W [3]

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(vi) Assume that for both wavelengths emitted by the lamp, the emitted photons are incident on the metal with the same intensity, and the ratio of photons absorbed to photoelectrons emitted is 1.

Sketch on Fig. 8.2 two graphs to show the variation with potential difference of the photoelectric current for

1. the 405 nm light alone,
2. the UV light alone.

Label your graphs (1) and (2) respectively [2]

(b) The variation of stopping potential V_S with different frequencies f of incident light is given by the expression

$$V_S = \frac{hf}{e} + C$$

where h is the Planck constant, e the elementary charge, and C is a constant.

The student repeats the experiment in **(a)** with different sources of light, measuring the stopping potentials V_S for different frequencies f of incident light on the sodium metal.

Fig. 8.3 shows the readings obtained.

f / 10^{14} Hz	V_S / V
6.0	0.21
6.6	0.45
7.2	0.72
9.1	1.49
10.5	1.86

Fig. 8.3

(i) Complete Fig. 8.3 using the experimental data in Fig. 8.2. [1]

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(ii) A graph of some of the data showing the variation of stopping potential V_S with frequency of incident light f is shown in Fig. 8.4.

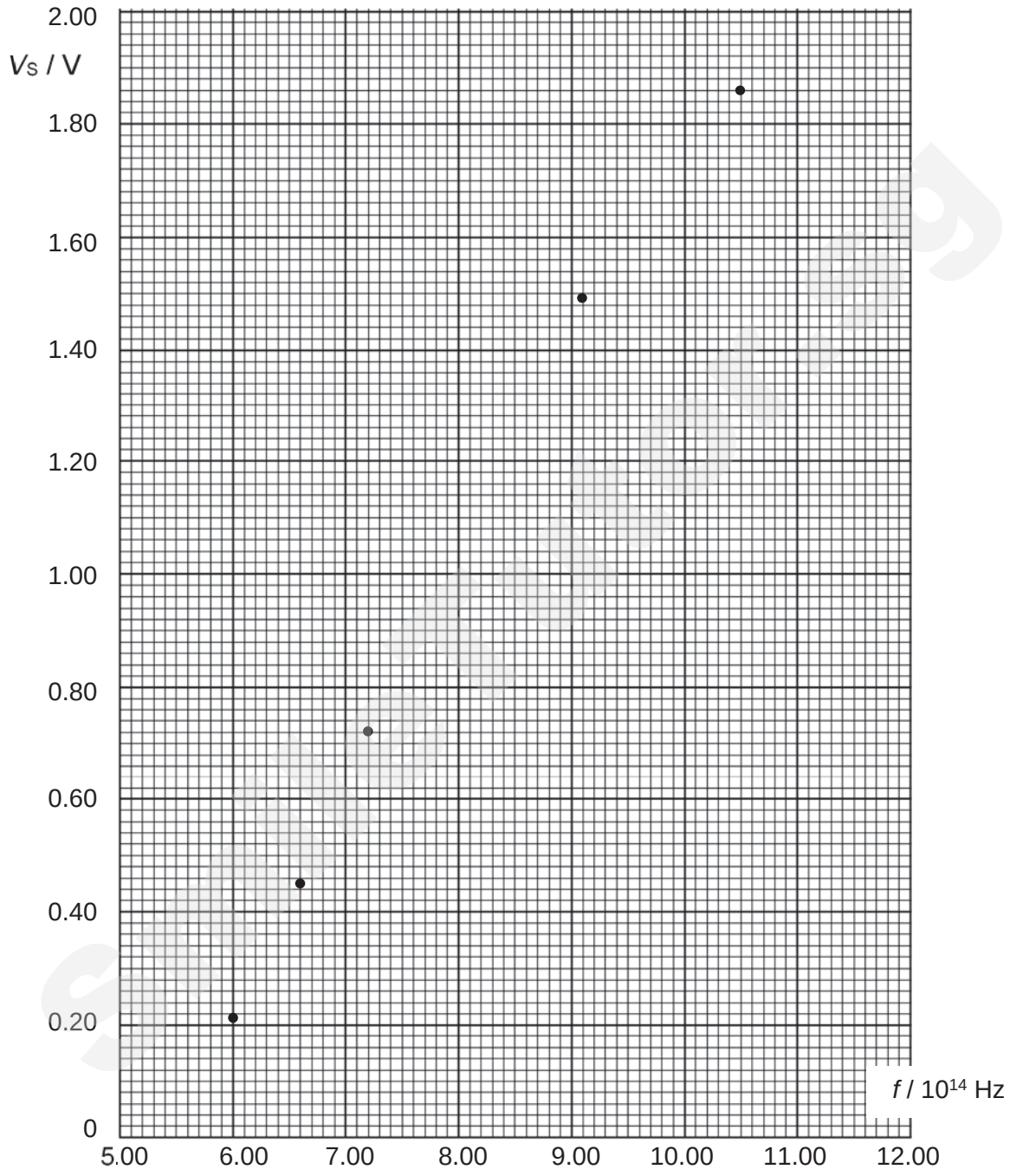

Fig. 8.4

On Fig. 8.4,

1. plot the point corresponding to your answer in **(b)(i)**,
2. draw the line of best fit for the points. [2]

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(iii) Determine the gradient of the line you have drawn on Fig. 8.4.

gradient = …… [2]

(iv) Explain, with calculations, whether the graph of Fig. 8.4 supports the expression given in **(b)**.

……

……

…… [2]

(v) Explain using the expression in **(b)**, how the graph in Fig. 8.4 would change if the sodium metal was replaced with calcium metal which has a larger work function.

……

……

…… [2]

END OF PAPER

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9749 / 3
PAPER 3
20 SEPTEMBER 2017

2 HOURS

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	6								

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer all questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of 24 printed pages and 1 blank page.

FOR EXAMINERS' USE	
Section A – do all questions	
1	**/ 15**
2	**/ 10**
3	**/ 10**
4	**/ 10**
5	**/ 10**
6	**/ 5**
Section B – do ONE question only	
7	**/ 20**
8	**/ 20**
Deduction	
TOTAL	**/ 80**

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

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work done on / by a gas	$W = p\Delta V$
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mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
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velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{(x_0^2 - x^2)}$
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resistors in series,	$R = R_1 + R_2 + \ldots$
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electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
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radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section in the spaces provided.

1 Ion beams consist of a stream of charged particles fired in a particular direction at a uniform speed. They may be used to impart kinetic energy onto a target.

(a) One method of treating cancer involves using ion beams to knock carbon nuclei out of cancer cells.

An ion, travelling with speed v, undergoes a head-on elastic collision with a carbon nucleus that was initially at rest, as shown in Fig. 1.1.



Fig. 1.1

(i) Given that the carbon nucleus has 12.0 times the mass of the ion, determine the final speed of the carbon nucleus just after the collision in terms of v.

final speed of the carbon nucleus = ……. [3]

(ii) If the ion in part **(i)** is replaced with an ion of equal mass as the carbon nucleus, but kinetic energy remains unchanged, suggest whether it would be more effective at knocking out the carbon nuclei, and briefly explain why.

……

……

…….. [2]

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(b) Ion beams may also be used to provide very small amounts of thrust. In 2019, NASA will be using spacecraft with a new ion engine that uses xenon ions to manoeuvre.

Consider a small spacecraft in space with a mass of 500 kg moving towards the right at a uniform speed of 13.0 km s^{-1}. Its engine fires a beam of xenon ions downwards at a speed of 40.0 km s^{-1} at a rate of 2.29×10^{19} ions per second, as shown in Fig. 1.2. These ions each have a mass of 2.18×10^{-25} kg.

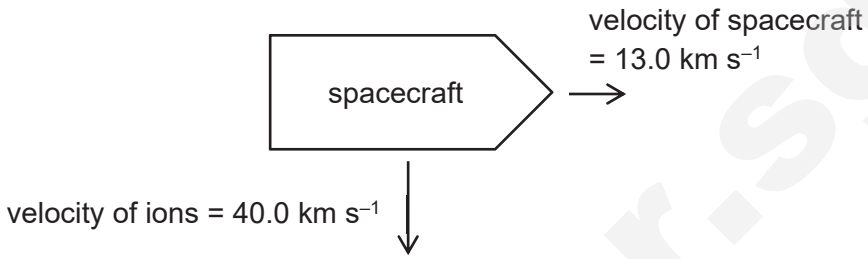

Fig. 1.2

(i) State the direction of the acceleration of the spacecraft.

…….. [1]

(ii) Show that the ion beam causes the spacecraft to accelerate with a magnitude of 3.99×10^{-4} m s^{-2}.

[3]

(iii) Hence determine the vertical displacement of the spacecraft after it has travelled a horizontal distance of 1.00 km.

displacement = ……. m [3]

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(iv) Before firing the ion beam, the spacecraft was travelling at uniform velocity. An unsecured 2.00 kg toolbox was floating stationary relative to the spacecraft. The dot in Fig. 1.3 shows the initial location of the box. Subsequently the ion beam fires continuously for a very long period of time.

On Fig 1.3, draw a cross (×) to indicate where the position of the box will be **after** the ion beam has been fired for a long period of time but is still continuing to fire.

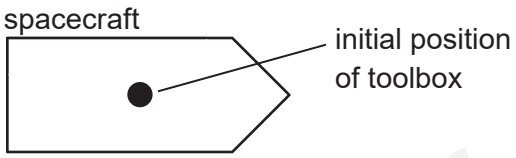

Fig. 1.3

[1]

(v) Hence or otherwise, determine the magnitude of net force on the box in the position indicated in part **(iv)** while the ion beams are still firing.

net force = …… N [2]

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2 Computer keyboards use a specialised spring mechanism so that the key pops back up after the user releases it. The magnitude of the total **upward** restoring force F exerted by the springs when pressing the key **downwards** is different from that when releasing the key, as shown in Fig. 2.1.

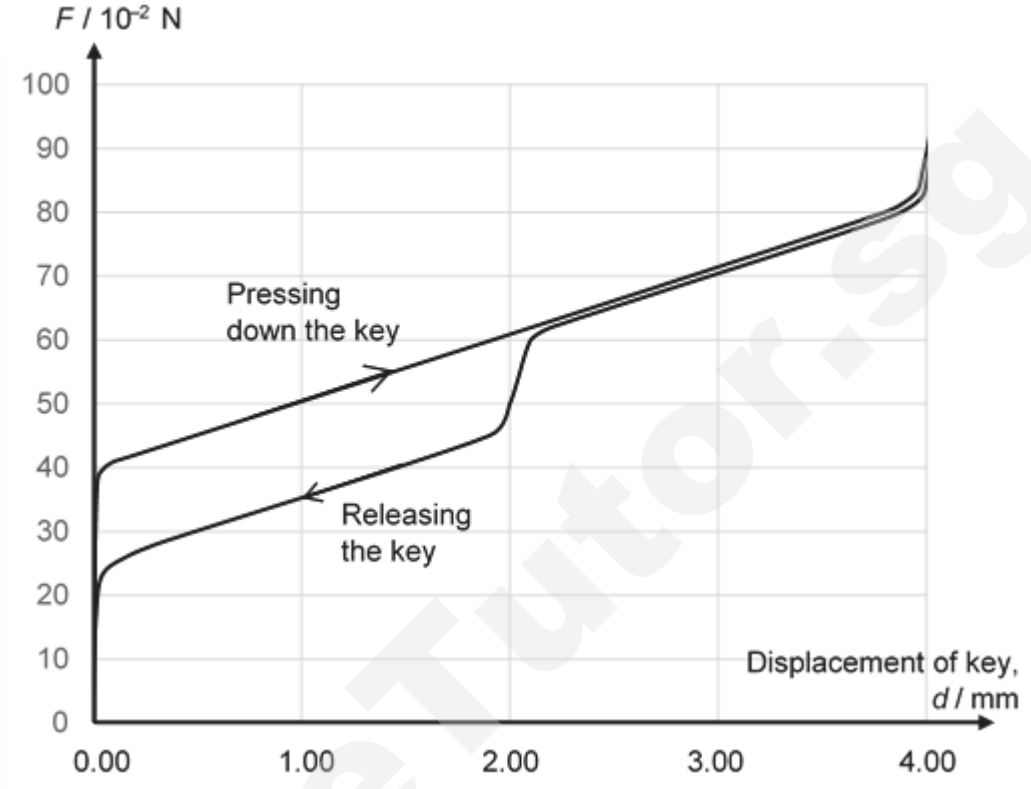

Fig. 2.1

(a) (i) Estimate the magnitude of work done by the restoring force when the key is pressed down from 0.00 mm to 4.00 mm.

work done = ... J [2]

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(ii) Keyboard specifications are usually given in terms of the amount of force required to press a key. This is measured by placing known masses on a key and noting how much force is required for it to be 'pressed' down.

An 80 g mass is placed on a 2.0 g key.
Determine the total change in gravitational potential energy of the key and mass if it travels downwards from 0.00 mm to 4.00 mm.

change in gravitational potential energy = …… J [2]

(iii) Hence or otherwise, state and explain whether the key can reach 4.00 mm if the key and mass begin from rest at 0.00 mm.

……

……

…… [2]

(b) **(i)** A keystroke is defined as pressing down a key from 0.00 mm to 4.00 mm, and then returning back to 0.00 mm.

Estimate the net amount of work done by the restoring force of the springs in one keystroke.

net work done by restoring force = …… J [2]

(ii) Top competitive gamers may perform up to 500 keystrokes per minute.

Estimate the average power output of the gamer's fingers.

power output = …… W [2]

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3 **(a)** Two planets, P and Q, are orbiting about a point O, which is the common centre of mass of the two planets. Planet P has half the density of Q, but twice the radius of Q.

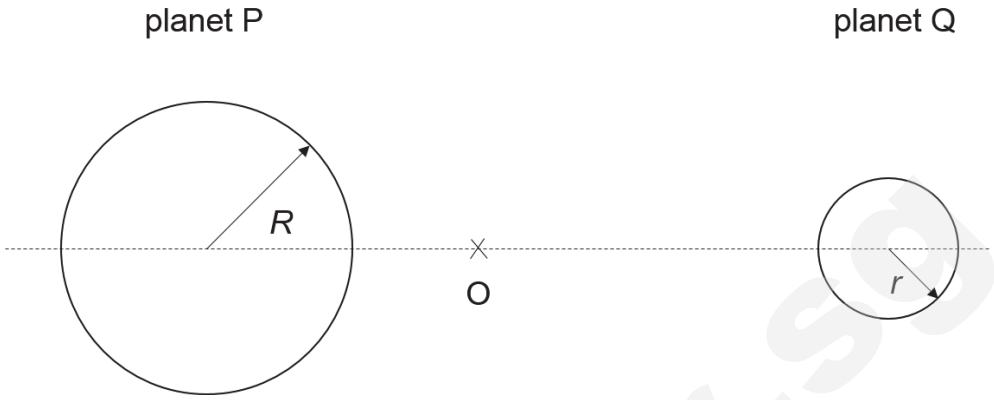

Fig. 3.1

(i) Show that the ratio of masses of planet Q to planet P is given by $\frac{1}{4}$.

[2]

(ii) Planet P is found to have an orbital period of T and the distance from the surface of planet P to the surface of planet Q is $10R$.

Hence, derive an expression for the radius of orbit of planet P.

[3]

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(b) A circular motion experiment is conducted on the surface of planet P. A pendulum bob of mass *m* tied to a string of length *L* is set to swing in a horizontal circle. The string makes an angle of 35° with the vertical, as shown in Fig. 3.2. Take the gravitational acceleration to be *g*.

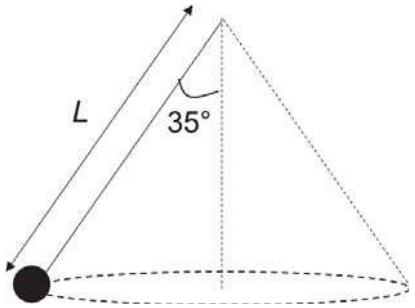

Fig. 3.2

(i) Determine the tension in the string in terms of *m* and *g*.

tension = ... [2]

(ii) Hence, determine the expression for the speed of the bob in terms of *g* and *L*. Leave the numerical part of your answer to 2 s.f.

[3]

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4 **(a)** With reference to a point in an electric field, define the term *electric potential*.

……

……

…… [1]

(b) A system of two identical, negatively charged particles X and Y, each of mass 2.7×10^{-26} kg and charge -3.2×10^{-19} C are held at a distance 1.0×10^{-9} m apart.

(i) Calculate the electric potential energy of the system.

electric potential energy = …… J [2]

(ii) Calculate the relative speed of separation when they are very far apart if they are released.

relative speed of separation = …….. m s^{-1} [3]

(iii) With the two charges held at rest at 1.0×10^{-9} m apart, a third charge Z is placed at the midpoint between charges X and Y so that the system of charges is stationary.

1. State and explain the sign of the third charge Z in order for the system of charges to be stationary.

……

……

…… [2]

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2. Calculate the magnitude of charge Z.

magnitude of charge Z = …….. C [2]

5 **(a)** Define magnetic flux.

……

……

…… [1]

(b) Fig. 5.1 shows a short coil wound over the middle part of a long solenoid. Both the coil and solenoid are made of wires with uniform cross-sectional area.

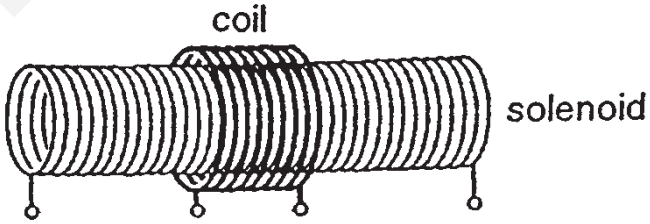

Fig. 5.1

A current passes through the solenoid, and the e.m.f. *E* induced in the short coil, varies with time *t* for one cycle of current, as shown in Fig. 5.2.

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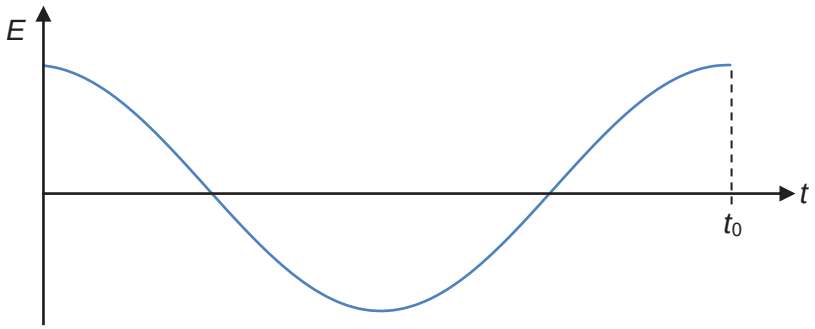

Fig. 5.2

Sketch, for one cycle of induced e.m.f., the variation with time of the

(i) flux ϕ in the **solenoid**,

[2]

(ii) net amount of charge Q which has flowed past a point in the solenoid.

[1]

(iii) Without changing other components in the setup, the number of turns per unit length of the solenoid in **(b)** is doubled.

By considering the magnetic flux, explain the changes (if any) to the induced current in the short coil.

……

……

……

…… [2]

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(c) Fig. 5.3 shows a long solenoid which has a small copper disc mounted at its centre. The disc spins on an axle which lies along the axis of the solenoid. The solenoid is connected in series with a d.c. supply and a resistor of resistance *R*. By means of brushes, one terminal of the resistor is connected to the rim of the disc and the other (terminal A) is connected to the axle via a voltmeter.

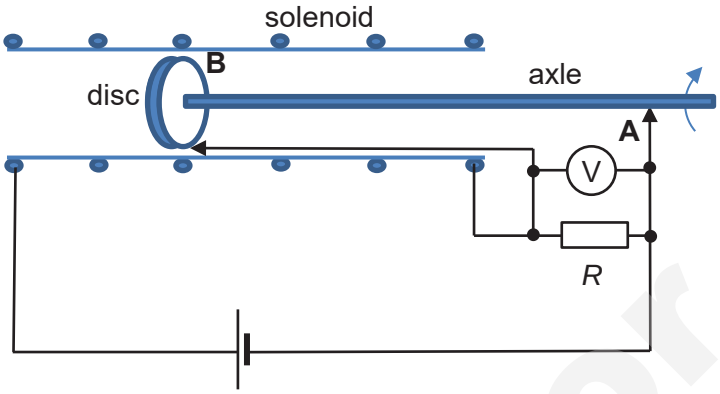

Fig.5.3

(i) Explain briefly why an e.m.f. is generated between the axle and the rim of the disc.

.....

.....

.....

..... [2]

(ii) Suggest, with explanation, the reading on the voltmeter if terminal A is connected to the rim of the disc at point B.

.....

.....

.....

..... [2]

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6 A pulse of radio wave lasts for 2.0×10^{-5} s. A photon of the radio wave may be considered to be at a point anywhere within this pulse, although the location of the point is not known.

Determine

(a) the uncertainty in the position of the photon,

uncertainty in the position of the photon = ... m [1]

(b) the uncertainty in the momentum of the photon,

uncertainty in the momentum of the photon = ... kg m s^{-1} [2]

(c) the uncertainty in the frequency of the photon,

uncertainty in the frequency of the photon = ... Hz [2]

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Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** The internal energy of a system is defined as the sum of random distribution of *kinetic and potential energies associated with the molecules of a system*.

(i) Comment on the origins of "*kinetic and potential energies associated with the molecules of a system*".

……..

……..

……..

…… [2]

(ii) Hence, explain how an increase in temperature relates to an increase in internal energy.

……..

……..

……..

…… [2]

(b) The heating of a solid can change it into a liquid, while the heating of this liquid can change it into a gas.

(i) Define the specific latent heat of a substance.

……..

…… [1]

(ii) Explain why the latent heat of vaporisation is greater than the latent heat of fusion.

……..

……..

……..

…… [2]

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(c) A cup of hot coffee purchased from the school canteen has a temperature of 85 °C. In order to drink the 250 g beverage before Physics lecture, a student placed five ice cubes, at –7.0 °C, of mass 5.0 g each, into the coffee. In order to speed up the rate of heat transfer, the student decided to stir the drink.

The following information is given:

latent heat of fusion of ice, l_f = 334 000 J kg^{-1}
specific heat capacity of ice c_I = 2100 J kg^{-1} K^{-1}
specific heat capacity of water c_W = 4200 J kg^{-1} K^{-1}
specific heat capacity of coffee c_C = 4300 J kg^{-1} K^{-1}

(i) Estimate the final temperature of the drink when all the ice has melted.

[3]

(ii) State two valid assumptions that you have made in your calculations.

……..

……..

……..

…… [2]

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(d) A cube of volume V contains N molecules of an ideal gas. Each molecule has a component v_x of velocity perpendicular to one side W of the cube, as shown in Fig. 7.1.

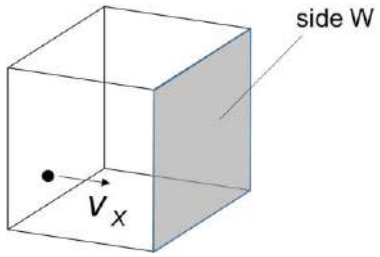

Fig. 7.1

The pressure p of the gas due to the component v_x of velocity is given by the expression

$$pV = Nm < v_x^2 >$$

where m is the mass of a molecule.

Explain how the expression leads to the relation

$$pV = \frac{1}{3} Nm < v^2 >$$

where $< v^2 >$ is the mean square speed of the molecules.

[3]

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(e) When air is pumped into a canister rapidly, the adiabatic process can be represented by the line with an arrow as shown in Fig. 7.2.

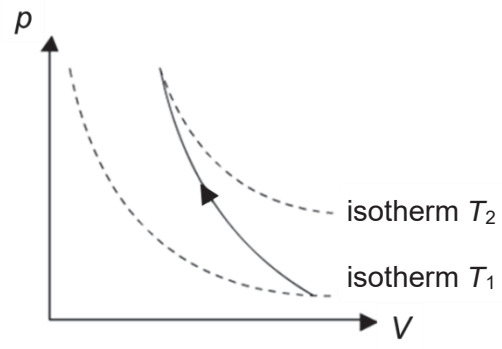

Fig. 7.2

(i) Explain how this type of change can be achieved.

……..

……..

……..

…… [2]

(ii) State two conditions that could have made this process possible.

……..

……..

……..

…… [2]

(iii) Hence, comment on the temperature T_2 of the air after pumping.

……..

…… [1]

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8 **(a)** The α-particle scattering experiment provided evidence for the existence of a nucleus.

Fig. 8.1 shows the paths of three α-particles moving towards a thin gold foil.

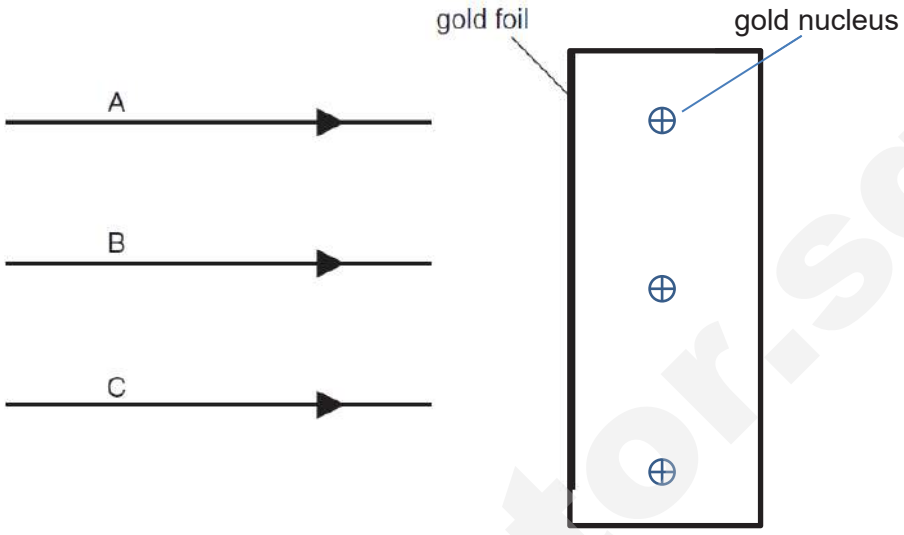

Fig. 8.1

Particle A is moving directly towards a gold nucleus.
Particle B is moving along a line which passes close to a gold nucleus.
Particle C is moving along a line which does not pass close to a gold nucleus.

(i) On Fig. 8.1, complete the paths of the α-particles A, B and C. [2]

State what could be deduced from the fact that

(ii) most α-particles were deviated through angles of less than 10°,

……

…… [1]

(iii) a very small proportion of the α-particles was deviated through angles greater than 90°.

……

……

…… [2]

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(b) An α-particle (${}^{4}_{2}\mathrm{He}$) is moving directly towards a stationary gold nucleus (${}^{197}_{79}\mathrm{Au}$).

The α-particle and the gold nucleus may be considered to be solid spheres with the charge and mass concentrated at the centre of each sphere.

When the two spheres are just touching, the separation of their centres is 9.6×10^{-15} m.

(i) The α-particle and the gold nucleus may be assumed to be an isolated system.

Calculate, for the α-particle just in contact with the gold nucleus,

1. the gravitational force it experiences,

gravitational force = …… N [2]

2. the electric force it experiences.

electric force = …… N [2]

(ii) Using your answers in **(b)(i)**, suggest why, when making calculations based on an α-particle scattering experiment, gravitational effects are not considered.

……

……..... [1]

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(c) In the α-particle scattering experiment conducted, the typical kinetic energy of the α-particles was 4.6 MeV.

(i) Estimate the closest distance of approach between an α-particle and a gold nucleus.

closest distance of approach = …… m [2]

(ii) Hence, suggest why the radius of the target nucleus could not be determined in this experiment.

……

……..... [1]

(d) The α-particles were mostly emitted from radon-222 gas which is a decay product of the radium-226 sample used in the experiment. The half-lives of radium-226 and radon-222 are 1.60×10^3 years and 3.82 days respectively.

(i) For a 5.0 mg sample of radium-226, show that there are 1.3×10^{19} radium nuclei.

[1]

(ii) Hence, deduce the activity of the 5.0 mg of radium-226 sample.

activity of radium-226 = …… Bq [2]

(iii) If there were 5.0 mg of radium-226 sample at the time of the experiment, determine the time it would take for the activity of radium-226 sample to

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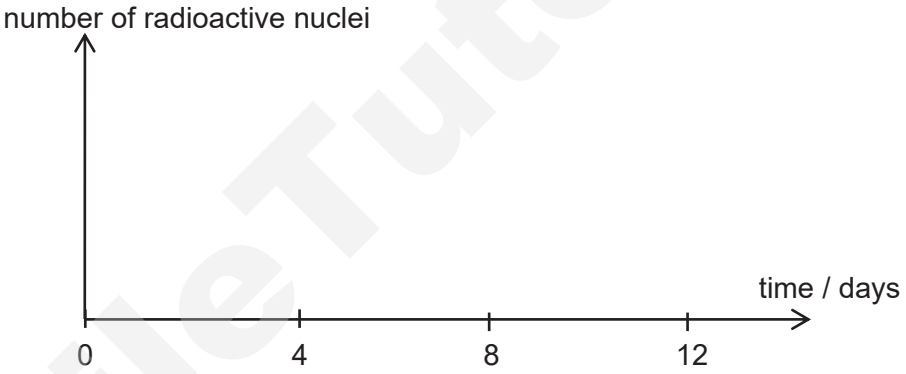
drop by 10%.

time taken = …….. years [2]

(iv) Using your answers from previous parts, sketch the variation with time of the number of radioactive nuclei of radium (label U) and radon (label O) on the axes provided, assuming there are equal numbers of both at the start.

Assume background radiation is negligible.



[2]

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIM EXAMINATIONS II

H2 PHYSICS 9749
PAPER 4
28 AUG 2017

2 HRS 30 MIN

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	6								

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, class and index number above.

Candidates answer on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

SHIFT	
LABORATORY	
FOR EXAMINERS' USE	
1	**/15**
2	**/ 8**
3	**/ 20**
4	**/ 12**
TOTAL	**/ 55**

This document consists of **14** printed pages.

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1 This investigation considers the time required to discharge a capacitor. Capacitors accumulate charge from a source of e.m.f., and discharges over a period of time when connected to a load.

(a) You are given a capacitor, a resistor of resistance r, a 2.00 V battery, a switch, an analog voltmeter and a digital multimeter that has been set to measure current in microamperes. The terminal of the capacitor labelled as "+" must be connected to the positive terminal of the battery, as shown in Fig. 1.1.

Using the digital multimeter as a microammeter (μA), set up the circuit as shown in Fig. 1.1.

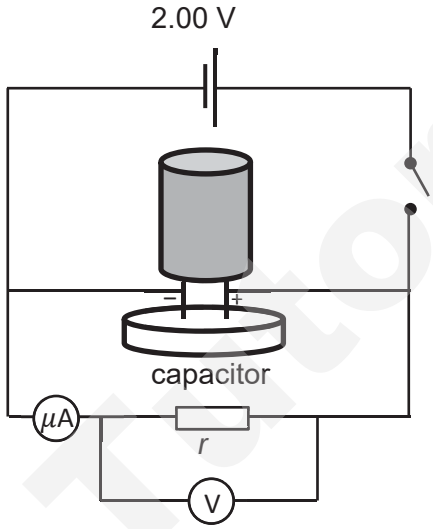

Fig. 1.1

(i) Close switch *S*.

(ii) The current through the ammeter will increase for a very short period of time. Measure and record the magnitude of the maximum current I_0 passing through the ammeter when the current stops increasing.

I_0 = ... [1]

(iii) Record the reading on the voltmeter V_0.

V_0 = ...

(iv) Open switch *S*.

(v) Given that $V_0 = I_0 r_{eff}$, calculate the effective resistance r_{eff} of the resistor and voltmeter in parallel.

r_{eff} = ... [1]

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(b) **(i)** Close switch S.

(ii) When the ammeter reading is equal to I_0, open switch *S* and start the stopwatch.

(iii) Record the time *T* taken for the ammeter reading to fall from I_0 to $I_0/2$.

T = ... [1]

(iv) Estimate the percentage uncertainty in your value of *T* in **(b)(iii)**.

percentage uncertainty = ... [1]

(c) **(i)** Close switch *S*.

(ii) When the ammeter reading is equal to I_0, open switch *S* and start the stopwatch.

(iii) At time *T* as found in **(b)(iii)**, measure and record V_T, the voltage across the resistor at that instant.

V_T = ... [1]

(iv) Using the values obtained above, determine the effective resistance r_T of the system at time *T*. Show your working clearly.

r_T = ... [1]

(d) In another similar setup, the resistor is replaced with a light bulb. When V_0 was applied across the light bulb and voltmeter, the current I_0 passing through the light bulb was found to be 0.400 A.

Use your results to predict the current $I_{1/2}$ that passes through the light bulb when the voltage across the light bulb and voltmeter is equal to $V_0/2$.

$I_{1/2}$ = ... [1]

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(e) It is suggested that the **time** $t_{1/2}$ required for the current passing through the ammeter to decrease to half its initial value is directly proportional to the **effective resistance** R, and is not affected by the magnitude of the **e.m.f. provided**.

Making use of the additional accumulator and resistor, take further measurements to investigate this suggestion.

State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

……

……

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……

…… [5]

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(f) One common application of such circuits is to power the bright flashes used in photography. Connecting a capacitor to a battery allows it to charge up, and when connected to a load such as a camera flash, it discharges by releases energy over a certain length of time. Outdoor photographers may find that the camera flash functions differently during extremely cold winters.

Suggest one change that could be made to this investigation in Singapore to safely study how the discharge time changes at different temperatures. State any relevant precautions or steps taken to quantify this change.

……

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…… [3]

[Total: 15 marks]

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2 In this experiment, you will investigate how the heating of a mass of boiling water is affected by the addition of metal mass of a different temperature.

(a) (i) Set up the apparatus as shown in Fig. 2.1.

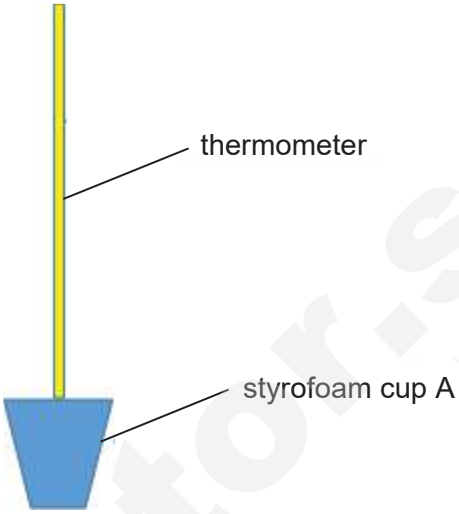

Fig. 2.1

Using a measuring cylinder, fill styrofoam cup A with 100 cm^3 of tap water.

Measure the temperature of the water, t_o.

t_o = ...

(ii) Fill styrofoam cup B with hot water of temperature t_h between 55 °C to 90 °C and place the 100 g mass provided in it. Stir the water and wait for the temperature to stabilise.

Measure the temperature of the hot water with mass, t_h.

t_h = ... [1]

(iii) With a string, transfer the 100 g mass from the cup B to cup A.
Stir the water and wait for the temperature of cup A to stabilise.
Measure the final temperature T of the water and masses in cup A.
Remove the mass and pour away the water in cup A.

T = ... [1]

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(b) Repeat **(a)** for three different values of temperature between 55 °C and 90 °C for t_h for the given mass.

Complete Fig. 2.2.

t_o / °C	t_h / °C	T / °C	($T - t_o$) / °C	($t_h - T$) / °C

Fig. 2.2 [2]

(c) It is suggested that the relationship between temperature increase ($T - t_o$) in cup A and temperature decrease of the mass is related by

$$t_h - T = k\,(T - t_o)$$

where k is a constant.

(i) Using your data in Fig. 2.2, plot ($t_h - T$) against ($T - t_o$), on Fig. 2.3.

($t_h - T$) / °C [2]

($T - t_o$) / °C

Fig. 2.3

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(ii) Hence determine the gradient of the plotted graph in Fig. 2.3.

gradient = …… [1]

(d) Describe one source of uncertainty or limitation of the procedure for this experiment.

……

……

…… [1]

[Total: 8 marks]

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3 In this experiment, you will investigate the length of a loaded spring as the load is varied.

(a) Measure and record the length L of the long metal rod as shown in Fig. 3.1.

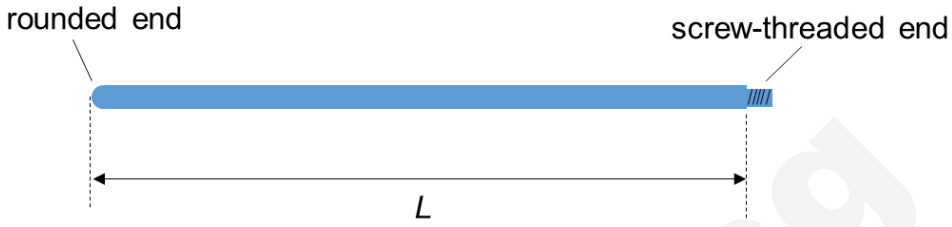

Fig. 3.1

L = ...

(b) **(i)** Support the rod as shown in Fig. 3.2.

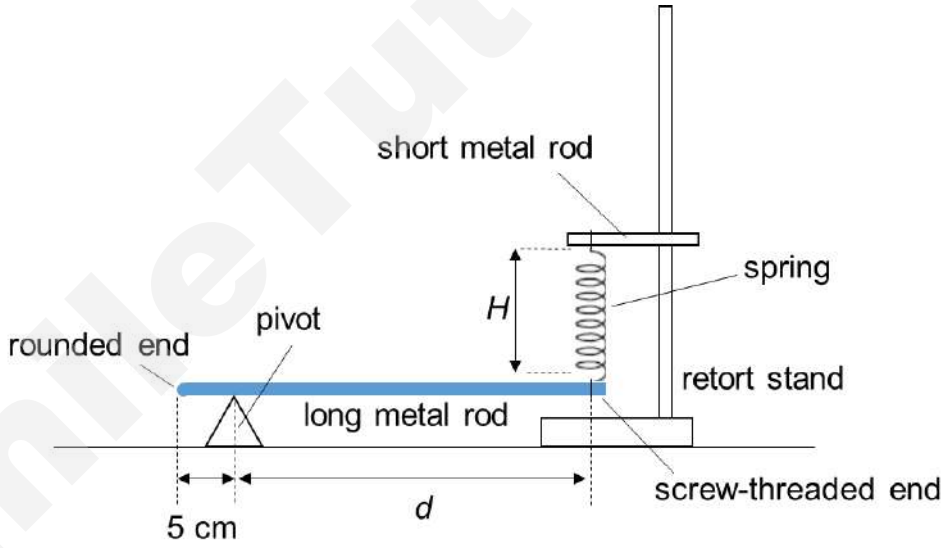

Fig. 3.2

(ii) Adjust the position of the pivot so that it is approximately 5 cm from the free end of the rod.

(iii) Adjust the clamp so that the rod is horizontal and the spring is vertical.

(c) **(i)** Measure and record the length H of the coiled part of the spring and the distance d from the pivot to the point where the spring is hooked to the rod.

H = ... [1]

d = ...

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(ii) Estimate the percentage uncertainty in your value of *H.*

percentage uncertainty = …… [1]

(d) Repeat **(b)(ii)**, **(b)(iii)** and **(c)(i)** to obtain further sets of readings for *d* and *H*.

[6]

(e) Theory suggests that *d* and *H* are related by the equation

$$H = z\left(\frac{W}{k}\right)\left(\frac{1}{d}\right) + \left(\frac{W}{k}\right)$$

where *W* is the weight of the rod, *k* is the spring constant of the spring, given to be 25 N m^{-1} and *z* is a constant.

Plot a suitable graph to determine *W* and *z*.

W = ……

z = …… [4]

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[3]

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(f) Suggest a physical meaning for the constant z.

……

…….…… [1]

(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

……

……

…….…… [1]

(h) **(i)** State one significant source of error in this experiment.

……

……

...…… [1]

(ii) Suggest an improvement that could be made to the experiment to address the source of error identified in **(h)(i).** You may suggest the use of other apparatus or a different procedure.

……

……

...…… [1]

(i) Sketch another line on your graph to represent an experiment performed with a heavier rod. Label this graph **Q**.

[1]

[Total: 20 marks]

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4 Beta particles can be deflected by magnetic fields.

Design a laboratory experiment to investigate how the magnetic flux density B of a magnetic field affects the angle θ through which beta particles are deflected when they pass through a uniform magnetic field.

The only radioactive source that is available to you emits α, β and γ radiation.

You should draw a diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) the procedure to be followed,
(b) the method by which beta particles **only** would be detected,
(c) the method of measuring the angle of deflection,
(d) how the magnetic field would be produced, measured and changed,
(e) any reliability and safety precautions you would take.

Diagram

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[Total: 12 marks]

END OF PAPER

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PRELIMINARY EXAMINATIONS II
H2 PHYSICS 9749/1 answers

1	A	**11**	A	**21**	D
2	B	**12**	C	**22**	D
3	C	**13**	D	**23**	C
4	D	**14**	A	**24**	A
5	A	**15**	A	**25**	B
6	B	**16**	C	**26**	C
7	D	**17**	D	**27**	B
8	B	**18**	C	**28**	A
9	A	**19**	B	**29**	C
10	B	**20**	D	**30**	C

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PRELIMINARY EXAMINATIONS II
H2 PHYSICS 9749/2 suggested answers

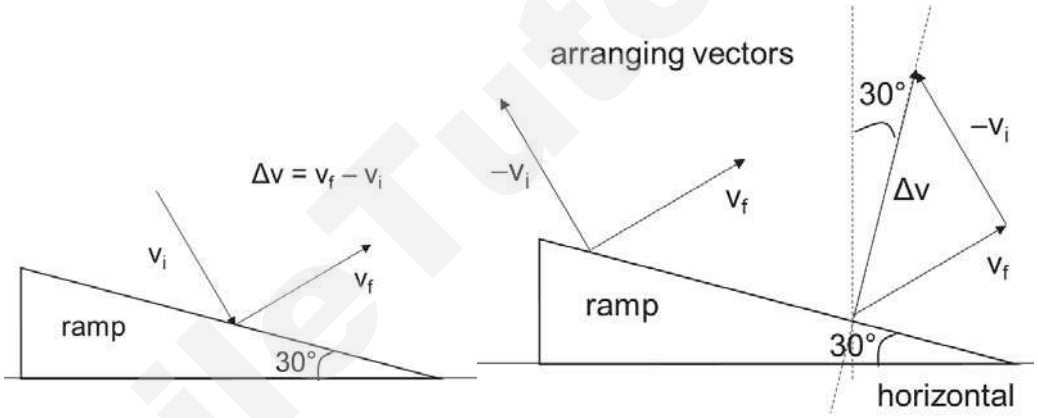
1 (a) (i)

- Systematic errors have same magnitude while random errors have different magnitude.
  Or
  Systematic errors are predictable depending on the conditions while random errors are not.
- Systematic errors are either consistently larger or smaller than the true value while random errors scatter about a mean value. (refers to sign of the error)
- Systematic error can be eliminated while random error can only be reduced.

[Award 1 mark for each comparison]

(ii) Random errors can be reduced by plotting a graph and drawing a line of best fit for the points. (do not accept "averaging of data")

(b)



M1 for determining the direction of Δv using $\Delta v = v_f - v_i$

Since Δv is 90° to the surface of the ramp, Δv is 60° with respect to the horizontal [A1]

$$A^2 = B^2 + C^2 - 2BC\cos A$$
$$\Delta v^2 = 5^2 + 5^2 - 2(5)(5)\cos 90^\circ \quad \text{[M1]}$$

$$\Delta v = 7.1\ m\ s^{-1} \quad \text{[A1]}$$

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(c)

$$\left(p+\frac{a}{V_m^2}\right)(V_m-b)=RT$$

$$pV_m-pb+\frac{aV_m}{V_m^2}-\frac{ab}{V_m^2}=RT$$

$$b=V_m \text{ and } a=pV_m^2$$

$$\text{unit of } b=m^3mol^{-1}$$

$$\text{unit of } a=Pa\,m^6mol^{-2}=kgm^5s^{-2}mol^{-2}$$

2 **(a)** Horizontal:

$s=vt\cos\theta$ [M1]

Vertical:

$v_f-v_i=at$

$v_f=-v_i=v\sin\theta$

$\frac{2v\sin\theta}{g}=t$ [M1]

Combining both,
[M1 for the act of combining together]

$$s=\frac{2v^2\sin\theta\cos\theta}{g}$$

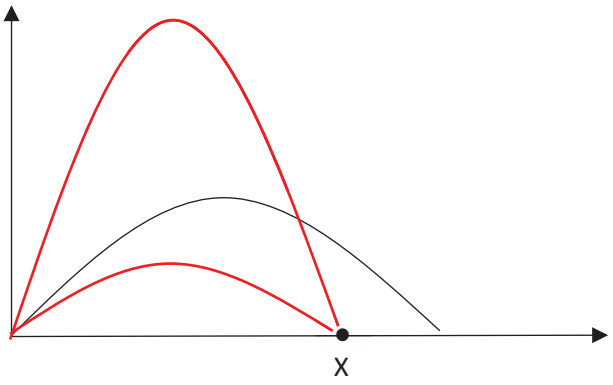
$$=\frac{v^2\sin 2\theta}{g}$$

(b)

$$d=\frac{v^2\sin 2\theta}{g}$$

Max d occurs when sin 2Θ = 1 and Θ = 45 deg [1]

(c)



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3 (a) **Density** is defined as the mass per unit volume of a substance.

Pressure is defined as force per unit area, where the force is acting at right angles to the area.

(b) The force F on a surface area A due to surrounding pressure p is given by

$$p = \frac{F}{A}$$

(Note: This force is directed perpendicularly into the surface.)

$$p = \frac{mg}{A}$$

Since density, ($\rho = \frac{m}{V}$),

$$\therefore p = \frac{(\rho V)g}{A}$$

where V is the volume of the fluid above the cross-sectional surface ($V = hA$),

$$\therefore p = \frac{\rho(hA)g}{A} = \rho gh$$ [M1 – do not allow marks for just giving the formula]

⇨ Hence, the pressure at the top face of the body is $p_1 = \rho g h_1$
and force F_1 is $F_1 = \rho g h_1 A$ [M1]

⇨ Similarly, the pressure at the bottom face of the body is $p_2 = \rho g h_2$
and force F_2 is $F_2 = \rho g h_2 A$

⇨ Hence, these two forces result in an upward force on the body,
Upthrust = $F_2 - F_1 = \rho g(h_2 - h_1)A = lA\rho g = V_{\text{fluid displaced}}\rho g$ [A1]

(c) **(i)** Upwards – Upthrust from centre of mass of displaced fluid.
Downwards – Weight from CG

(ii) $upthrust = \rho g V$
Resultant force = upthrust – weight of wood
= (1000 – 430) x 9.81 x 7 x 10^{-5}
= 0.391 N

(iii) F=ma
a= 0.391/0.295 = 1.32 ms^{-1}

$s = ut + \frac{1}{2} at^2$

$0.05 = \frac{1}{2} (1.32) t^2$

t = 0.275 s

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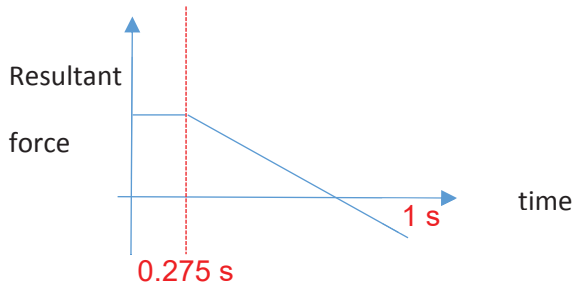
(iv)



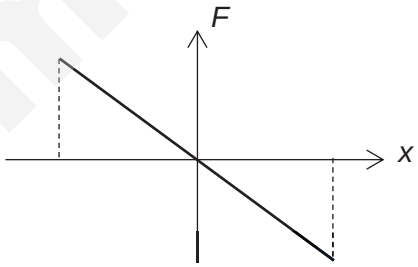
4 (a) (i) Taking right as positive,
force due to left spring = $-k(e + x)$ and
force due to right spring = $k(e - x)$ C1
resultant force = $-k(e + x) + k(e - x)$ M1
$= -2kx$

(ii) For SHM, $a = -\omega^2 x$ and from (a)(i), $F = -2kx = ma$ (from Newton's second law), hence $a = -(2k / m)x$
so a is directly proportional to x and oppositely directed.

(b) (i) $a = -\omega^2 x = -(2k / m)$
$F = -2kx = m$
so $\omega^2 = 2k / m$
$= (2 \times 9.0) / 0.037$
$\omega = 22$ rad s^{-1}

(ii) Solution 1:
total energy of SHM = $\frac{1}{2}m\omega^2 x_0^2$
$= \frac{1}{2} \times 37 \times 10^{-3} \times (22)^2 \times (2.8 \times 10^{-2})^2$
$= 7.0 \times 10^{-3}$ J

Solution 2:
total energy of SHM = WD on system = $\frac{1}{2} F x$ where $F = -2kx$



Solution 3:
1. At equilibrium, EPE of 2 springs = $2 \times \frac{1}{2}ke^2 = ke^2$
2. Displaced by x to the right, EPE of 2 springs = $\frac{1}{2}k(e + x)^2 + \frac{1}{2}k(e - x)^2$
$= ke^2 + kx^2$
3. Total energy of oscillations = WD on system = Gain in EPE = kx^2

(iii) Solution 1:
$E_K = E_P$
$\frac{1}{2}m\omega^2 (x_0^2 - x^2) = \frac{1}{2}m\omega^2 x^2$
$x = x_0 / \sqrt{2} = 2.8 / \sqrt{2}$
$= 0.020$ m

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$E_K = E_P = ½E_T$ (because $E_K + E_P = E_T$ and $E_K = E_P$)
Solution 2:
$E_K = 3.5$ mJ
$E_K = ½m\omega^2 (x_0^2 - x^2)$

Solution 3:
$E_P = 3.5$ mJ
$E_P = ½m\omega^2x^2$

5 (a) (i)

Wavelength is found by

$$\lambda = \frac{v}{f} = \frac{3.00 \times 10^8}{3.0 \times 10^4} = 10^4 \text{m}$$

Phase difference is found by

$$\frac{\phi}{2\pi} = \frac{\text{d}}{\lambda}$$

$$\phi = \frac{2\pi d}{\lambda} = \frac{2\pi(5 \times 10^3)}{10^4} = \pi$$

(ii) Three possible reasonings accepted:

Waves travelling by Path B undergo a total phase difference of 3π (2π from path, π from reflection). [π also accepted as an answer]

Since the phase difference between the two paths is 2π, it undergoes constructive interference.

Path difference between the two waves give a phase difference of π.

After the phase change due to reflection, the total phase difference is 2π, hence constructive interference.

After waves on path B have hit the ground and reflected, they are in phase with the source.

Since they are in phase with the source, and distance from source to antenna is same as distance from ground to antenna, the waves on both paths will be in phase with each other at the antenna and constructive interference occurs.

(b) (i) Possible accepted answers take two forms:

- If the waves are emitted in all directions, the intensity of the wave decreases proportional to r^2 **OR** some energy is not delivered to the antenna.
- In contrast, since the wave is confined inside the tube, 100% of energy is delivered to the antenna.

Note: "nearly all energy" also accepted as student is accounting for real life energy losses

- Stating that all the waves are collected at antenna instead of being diffused.
- Stating that hence the intensity (or power) is greater vs being dispersed.

(ii) Standing waves form when two waves of **same speed/frequency/wavelength** *(pick 2 out of 3)* meet each other travelling in **opposite** directions (*Note: Mark not given if student does not mention these conditions)*

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When waves **reflect off the inside of the waveguide**, the incident and reflected waves thus form standing waves.
*Do not accept "waves reflect off open end", but can accept if student says wave reflects off **antenna**.*

(c) Lower frequency means higher wavelength.
Waves with a larger wavelength have wider diffraction, hence the 90.5 MHz broadcast is better able to diffract around the hill.

6 **(a)** **(i)** $R = V/I = 0.13 / 150$ C1
$= 8.7 \times 10^{-4}\ \Omega$ A1

(ii) $A = \pi r^2 / 4 = 4.524 \times 10^{-6}$ C1
$\rho = RA / l$ C1
resistivity of copper = $1.6 \times 10^{-8}\ \Omega$ m A1

(b) **(i)** number of electrons per unit volume,
$n = (1.6 \times 10^{18}) / [(4.524 \times 10^{-6})(0.24)]$
$= **1.474 \times 10^{24}\ m^{-3}$ C1

$I = nAve$ C1
drift velocity $v = 140\ m\ s^{-1}$ A1

** erratum: n should work out to be $8.45 \times 10^{22}\ m^{-3}$ for copper so the number of electrons in the cable should be 9.23×10^{22} instead of 1.6×10^{18}.

(ii) If the diameter of the cable is doubled, the cross-section area of the cable will be quadrupled.
Given that current, electron density and electronic charge are the same, drift velocity is a quarter of the calculated value because v is inversely proportional to A.

7 **(a)** Assume that transformer is 100% efficient, so power in primary coil is fully transferred to secondary coil in transformer.

$$I_{\text{transmission}} = \frac{P}{V} = \frac{1000000}{300000} = 3.3333\text{A}$$

$$\text{Power lost} = I^2R = \frac{10^2}{3}(8000) = 88888\text{W} \quad [\text{C1}]$$

$$= 89\,\text{kW (2sf)} \quad [\text{A1}]$$

(b) for equivalent d.c. voltage of 12 V,
single diode half-wave rectified a.c. peak square voltage = $12^2 \times 4 = 576$
peak voltage = $\sqrt{576} = 24\,\text{V}$

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r.m.s voltage for full sine-wave = $\frac{24}{\sqrt{2}} = 16.971\text{V}$

turn ratio = $\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{240}{16.971} = 14$

8 **(a)** **(i)** When potential difference is positive, photoelectric current remains constant at 370 μA.
[B1]
As potential difference decreases from zero, the photoelectric current decreases gradually to zero at a potential difference value of –1.11 V.
[B1]

Only award 1 mark if students describe the changes without quoting any values.

(ii) Reading horizontal intercept from graph.
–1.11 V
Acceptable magnitude range: $1.10 < V_s < 1.16$

(iii) $E_{photon} = \phi + E_{K\max}$

$$\frac{hc}{\lambda} = \phi + eV_s$$

$$\lambda = \frac{hc}{\phi + eV} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(2.3+1.11)(1.6\times10^{-19})} \quad \text{[C1]}$$

$$= 3.1472\times10^{-7} = 365\text{nm} \quad \text{[A1]}$$

Allow e.c.f. for stopping potential from (ii).

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(iv) $E_{photon} = \phi + E_{K\max}$

$$\frac{hc}{\lambda} = \phi + eV_s$$

$$V_s = \frac{\frac{hc}{\lambda} - \phi}{e} = \frac{\frac{(6.63\times10^{-34})(3\times10^{8})}{(405\times10^{-9})} - (2.3)(1.6\times10^{-19})}{1.6\times10^{-19}} \quad \text{[C1]}$$

$= 0.7694\,\text{V}$ [A1]

(v) $I = 370\times10^{-6}\ \text{A} = Q/t$

$$\frac{n}{t} = \frac{370\times10^{-6}}{1.6\times10^{-19}}$$

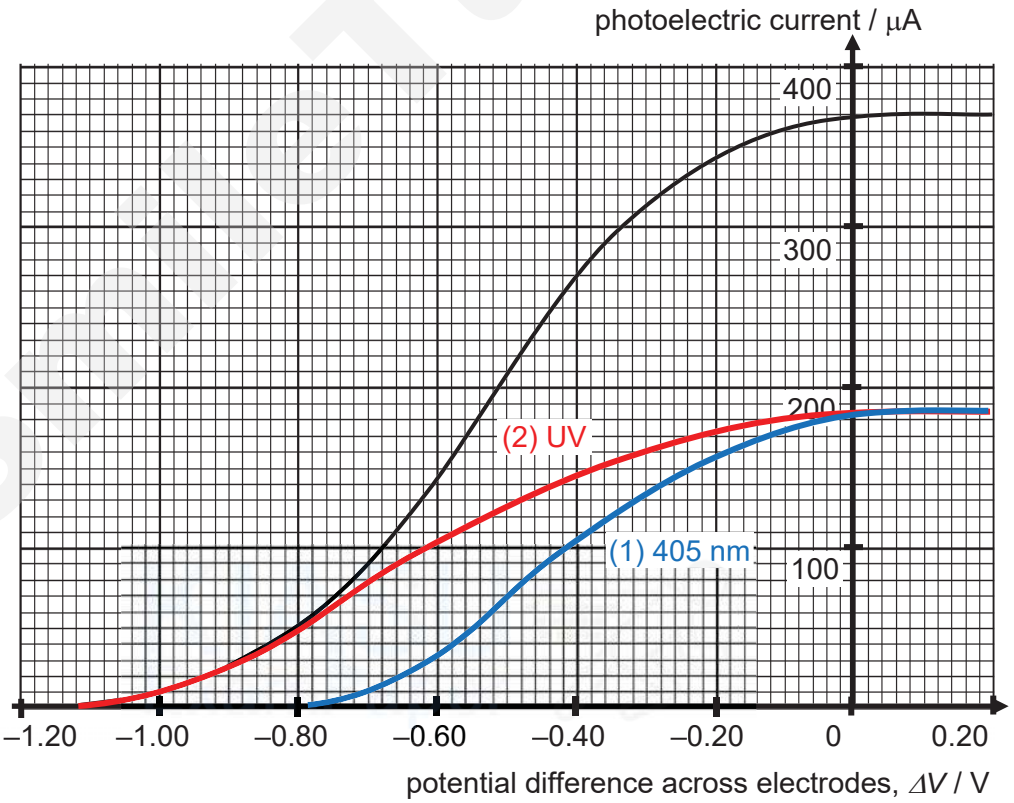
$$P = \frac{nhc}{t\lambda}$$

$$= (0.5)\frac{370\times10^{-6}}{1.6\times10^{-19}}(6.63\times10^{-34})(3\times10^{8})\left(\frac{1}{405\times10^{-9}} + \frac{1}{365\times10^{-9}}\right) \quad \text{[C1]}$$

$$= (0.5)2.39585\times10^{-3}$$

$= 1.2\times10^{-3}\ \text{W}$ [A1]

(vi)



Correct stopping potentials for (1) and (2) (allow ecf) [B1]
Correct saturation current at 185 μA [B1]
If curves are not smooth –1 mark

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(b) (i)

f / 10^{14} Hz	V_S / V
7.2	0.72
8.2	1.13
9.1	1.49

Correctly calculated values which follow dp of columns [B1]
Allow e.c.f using (7.4, 0.77) or other quoted V_s value from (a)(ii).

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(b) (ii)

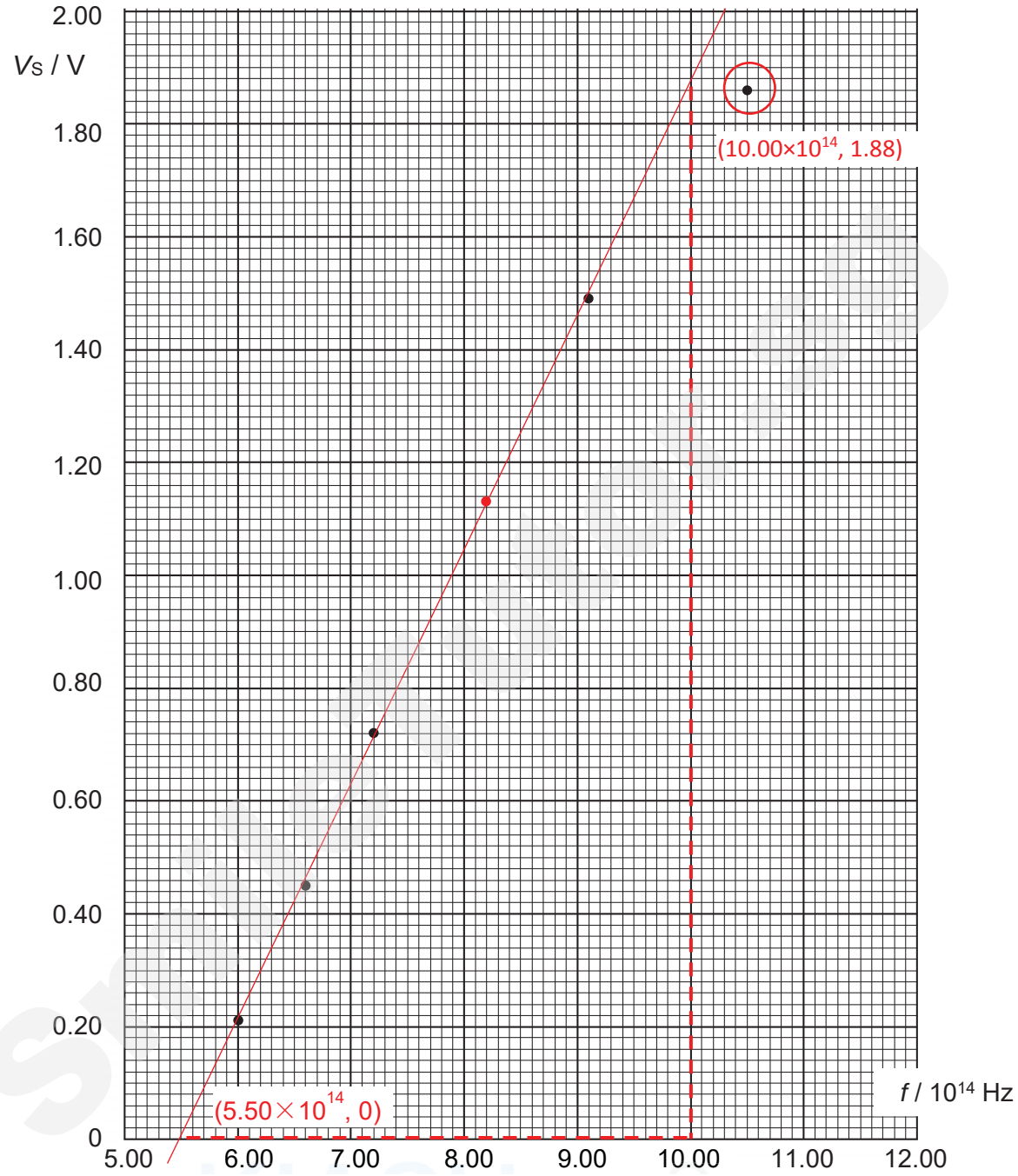

Fig. 8.4

Correctly plotted point **accurate to half smallest division** [B1]
Best fit line has appropriate scatter with identification of anomalous point [B1]

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(iii)

$$\text{gradient} = \frac{1.88 - 0}{10.00 \times 10^{14} - 5.50 \times 10^{14}} \qquad \text{[C1]}$$

$$= 4.17778 \times 10^{-15}$$

$$= 4.18 \times 10^{-15} \text{ Vs} \qquad \text{[A1]}$$

(iv) Gradient should represent h/e with theoretical value of 4.14×10^{-15}. [M1]
Calculated gradient is 0.88% deviation from theoretical value, which is insignificant. [B1]
Graph supports the expression given in (b). [A0]

(v) The vertical intercept *C* represents the negative value of work function of the metal divided by elementary charge. [B1]
If work function is larger, the graph will be shifted/translated downwards for a more negative vertical intercept. [B1]

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PRELIMINARY EXAMINATIONS II
H2 PHYSICS 9749/3 suggested answers

1 **(a)** **(i)**

Let m be the mass of the ion, v_{ion} be the final speed of the ion and v_c the final speed of the carbon nucleus. Take right as positive.
Momentum is conserved: $mv = mv_{ion} + 12mv_c$
Can simplify this to $v = v_{ion} + 12v_c$
Elastic collision: $v = v_c - v_{ion}$ Alternatively, apply conservation of energy
Solve for v_c by eliminating v_{ion}: $v = (v_c - v) + 12v_c$ $v_c = 2/13\ v = 0.154\ v$ (to 3 s.f.)

(ii) For collisions between two particles of **equal mass**, **all KE (or momentum)** is imparted / exchange speeds / similar answer
[note: do not award for "greater mass → more KE" (not always true)]
It will be **more effective.**

(b) **(i)** Upwards

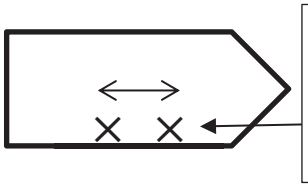
(ii)

Method 1:	Method 2:
The force exerted on the ions is equal to $F = \frac{dP}{dt} = \frac{d(mv)}{dt} = \frac{dm}{dt}v$	By CoM, each ion fired results in the spacecraft gaining $\Delta p = m_{xenon} \times v_{xenon}$
The rate at which mass is ejected is $\frac{dm}{dt} = \frac{dN}{dt} \times m_{xenon}$	Force is equal to the rate at which momentum changes: $F = \frac{\Delta p}{\Delta t} = \Delta p \times rate\ of\ fire$
Using F = ma, $m_{spaceship} \times a = \frac{dN}{dt} \times m_{xenon} \times v_{xenon}$ $a = \frac{(2.29 \times 10^{19})(2.18 \times 10^{-25})(40.0 \times 10^3)}{500} = 3.99 \times 10^{-4} m\,s^{-2}$	

(iii)

Time taken = 1 km / (13.0 km s^{-1}) = 0.0769 s
Apply s = ut + ½ a t^2 in the vertical direction: $s_y = 0 + \frac{1}{2}(3.99 \times 10^{-4})(0.0769)^2$
Answer is 1.18 × 10^{-6} m

(iv)



Accept a reasonable range of positions in the "middle". Should show no sideways movement.

Fig. 1.3

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	(v)	Box must accelerate together with the spacecraft.
		$F = ma = (2\ \text{kg})(3.99 \times 10^{-4}\ \text{m s}^{-2})$
		$F = 7.98\ \text{N}$
2	(a)	(i)	Work done is area under graph from (0.00,40) to (4.00,80) *[Mark given for identifying the correct values or parts of the graph, accept up to 90 for higher bound. For counting squares, the method mark will go to using the right number of squares.]*
			Area under graph: $\frac{1}{2} \times (4.00 \times 10^{-3}\ \text{m})(40 + 80) \times 10^{-2}\ \text{N} = 2.4 \times 10^{-3}\ \text{J}$ *[Mark is given for putting in the correct values and getting a result within the range of up to* $\pm 0.2 \times 10^{-3}$ *J]*
			[other methods of calculation or estimation also allowed, e.g. counting squares.]
		(ii)	$\Delta GPE = mgh = 0.082 \times 9.81 \times 0.004$ *(method mark given for either correct numbers put in, or if that isn't done, mark can be given if student explicitly writes the correct equation)*
			Ans: -3.2×10^{-3} J
		(iii)	Kinetic energy of the key at 4.00 mm is equal to |ΔGPE| – |WD| by *F*. Since KE of key is positive [or |ΔGPE| > |WD|], it is able to reach 4.00 mm. *[mark with ecf based on students' answers to (i) and (ii)*
	(b)	(i)	Conceptual understanding: • In one full loop, there is no change in GPE. • When pressing down the key, typist does work against spring, spring is doing negative work (i.e. storing potential energy). • When releasing the key, the spring is doing positive work to push the key back, i.e. typist is doing negative work. • Hence, net work done by the typist is positive while net work done by spring is negative. • Magnitude of net work is the area bounded the graph.
			Estimate area as a parallelogram from 0 mm to 2 mm: $A = 0.002\ \text{m} \times (15 \times 10^{-2}\ \text{N})$ *[other reasonable methods are allowed, e.g. finding area of other curve and* ***subtracting, counting squares, etc]***
			Ans: -3.0×10^{-4} J *[****accept up to*** $+1 \times 10^{-4}$ J; ***student loses A1 if*** $+^{ve}$ *ans is given]*
		(ii)	Average power = work done / time = rate of keystrokes × work done per keystroke = (500/60) × 3.0×10^{-4}
			Ans: 2.5×10^{-3} J *[mark magnitude of ans based on value provided by student in part (i). Accept* $+^{ve}$ *even if student gave positive value in part (i) to account for assuming magnitude; accept* $-^{ve}$ *ans iff student gave* $+^{ve}$ *ans in part (i)]*

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1 **(a)** Two planets, P and Q, are orbiting about a common point, O. Planet P has half the density of Q, but twice the radius of Q.

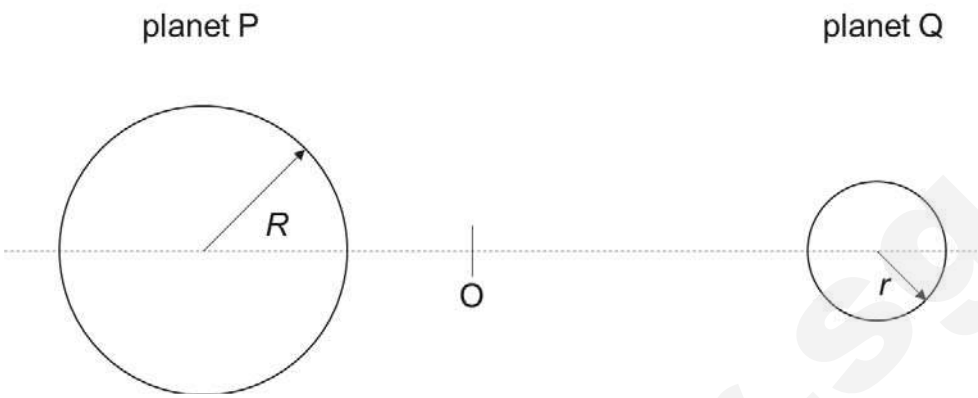

Fig. 2.1

(i) Show that the ratio of mass of planet Q to planet P is given by $\frac{1}{4}$. [2]

$m_P = \rho_P V_P \qquad V_P = \frac{4}{3}\pi R^3$

$m_Q = \rho_Q V_Q \qquad V_Q = \frac{4}{3}\pi r^3$ [M1]

$\frac{m_Q}{m_P} = \frac{\rho_Q V_Q}{\rho_P V_P} = \frac{2\rho_P (r)^3}{\rho_P (2r)^3}$ [M1]

$= \frac{1}{4}$ [A0]

(ii) Planet P is found to have an orbit period of *T* and the distance from the surface of planet P to planet Q is 10*R*. Hence, derive an expression for the radius of orbit of planet P.

Gravitational force provides for centripetal force [M1]

$\frac{Gm_P m_Q}{(11R + r)^2} = m_P x\omega^2$ [M1]

$x = \frac{Gm_Q T^2}{4\pi^2 (11R + r)^2}$ [A1]

Other forms of expression accepted as long as the Physics is correct

..... [3]

(b) A circ… planet P. A pendulum bob of mass *m* tied to a string of length *L* is set to swing in a horizontal circle. The string makes an angle of 35° with the vertical, as shown in Fig. 2.2. Take the gravitational acceleration to be *g*.

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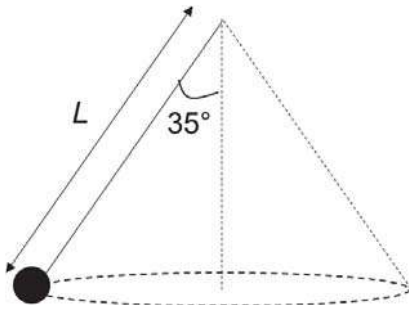

Fig. 2.2

(i) Find the tension in the string. [2]

vertical component of T = Tcos35° = mg [M1]

$$T = \frac{mg}{cos35°} = 1.22mg$$ [A1]

(ii) Hence, determine the expression for the speed of the bob. Leave the numerical part of your answer to 2 s.f.

radius of circular motion, r = Lsin35° [M1]

horizontal component of T = Tsin35°

$$Tsin35° = \frac{mv^2}{L}$$ [M1]

$$1.22gLsin^2 35° = v^2$$

$$v = 0.63\sqrt{gL}$$ [A1]

…….. [3]

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2 (a) With reference to a point in an electric field, define the term *electric potential*.

Definition of Electric Potential: The electric potential V at a point in an electric field is defined as the ***work done against the electric force per unit positive charge*** by an ***external agent*** in bringing a small test charge ***from infinity to that point*** (***without any net change in K.E.*** of the point charge).

……

……

……

[1]

(b) Two identical negatively charged particles X and Y, each of mass 2.7×10^{-26} kg and charge -3.2×10^{-19} C are held at a distance 1.0×10^{-9} m apart.

(i) Calculate the electric potential energy of the system.

$$\text{E.P.E. of system} = \frac{q^2}{4\pi\varepsilon_0 r}$$

$$= \frac{(-3.2 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times 1.0 \times 10^{-9}}$$

$$= 9.2 \times 10^{-19} \text{J}$$

electric potential energy = …… J [2]

(ii) Calculate the relative speed of separation when they are very far apart after they are released.

By the conservation of energy,

loss in E.P.E. of system = gain in K.E. of system

$$9.2 \times 10^{-19} = 2\left(\frac{1}{2}mv^2\right)$$

$$v = \sqrt{\frac{9.2 \times 10^{-19}}{2.7 \times 10^{-26}}}$$ M1

$$v = 5.8 \times 10^3 \text{ m s}^{-1}$$

relative speed of separation is 2 x 5.8×10^3 M1

$= 1.2 \times 10^4$ m s^{-1} A1

relative speed of separation = …… J [3]

(iii) With the two charges held at rest at 1.0×10^{-9} m apart, a third charge Z is placed at the mid-point along XY so that the system of charges is stationary.

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1. State and explain the sign of the third charge in order for the system of charges to be stationary.

In order for the either of the negative charges to be stationary, the resultant force must be zero. Since charge X exerts a repulsive force on charge Y, the third charge must exert an attractive force on charge Y, hence it must be a positive charge.[M1]

The sign of the third charge is positive.[A1]

..... [2]

2. Calculate the magnitude of charge Z.



$F_{YZ} = F_{YX}$

$$\frac{q_Y q_Z}{4\pi\varepsilon_0\left(\frac{1}{2}r\right)^2} = \frac{q_Y q_X}{4\pi\varepsilon_0 r^2}$$

$$\frac{q_z}{\left(\frac{1}{2}\right)^2} = q_x$$

$$q_z = \frac{1}{4}(3.2\times10^{-19})$$

$$q_z = 8\times10^{-20}\ \text{C}$$

magnitude of charge = ... C [2]

2 **(a)** Define magnetic flux.

Magnetic flux Φ is defined as the product of the area of the surface through which the field is passing, and the component of the magnetic flux density B that is normal (perpendicular) to this surface.

..... [1]

(b) Fig. 2.1 shows a short coil wound over the middle part of a long solenoid. Both the coil and solenoid are made of wires with uniform cross-sectional area.

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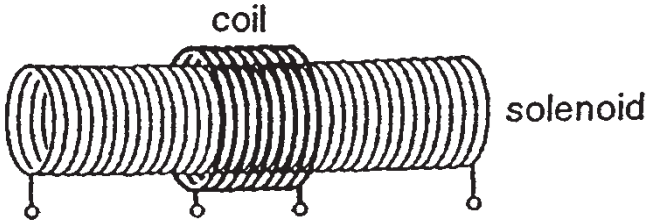

Fig. 2.1

The e.m.f. *E* induced in the short coil is varied with time *t* as shown in Fig. 5.2

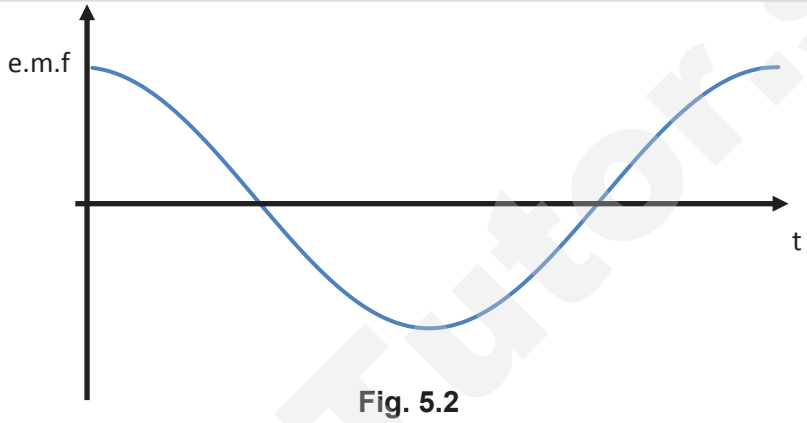

Fig. 5.2

Sketch the variation with time of the

		(i)	flux ϕ in the solenoid	[2]
			Negative sine curve.	
		(ii)	net amount of charge Q which has flowed past a point in the solenoid.	[1]

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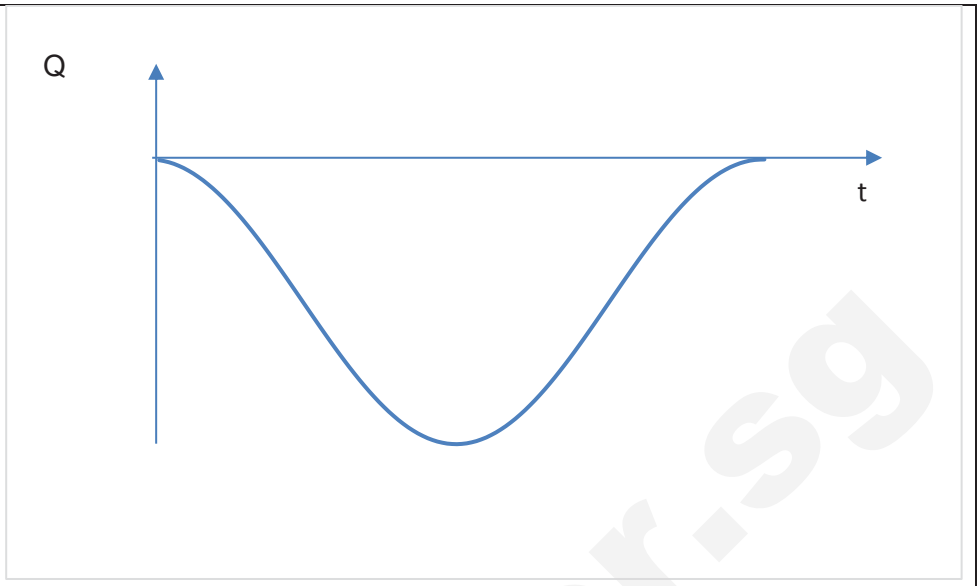

(iii) Without changing any other components in the setup, the number of turns of the solenoid in (ii) are increased to twice their original number each. Using the concept of magnetic flux, explain the changes (if any) to the induced current in the short coil.

In the transformer, the magnetic flux is the same in the primary and secondary coil.

As number of turns is doubled, the n is doubled but I is halved since the resistance is doubled. Hence, the magnetic flux at the solenoid remains the same. M1

The rate of change of Magnetic flux ($\phi = BA$) is the same on the primary and the secondary side.

$\Phi_p = N_p BA$

$\Phi_s = N_s BA$

$$E = -\frac{d\Phi}{dt} = -N\frac{d\phi}{dt}$$

Induced emf will halved because $\frac{d\phi_p}{dt} = \frac{d\phi_s}{dt}$ => $\frac{E_s}{N_s} = \frac{E_p}{N_p}$

Using conservation of Energy,

Hence, induced current will be doubled of the primary side. That will mean that the induced current is the same as before. A1

…… [2]

(c) Fig.5.3 shows a long solenoid which has a small copper disc mounted at its centre. The disc spins on an axle which lies along the axis of the solenoid. The solenoid is connected in series with a d.c. supply and a resistor of resistance *R*. By means of brushes, one terminal of the resistor is connected to the rim of the disc and the other (terminal A) is connected

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to the axle via a voltmeter.

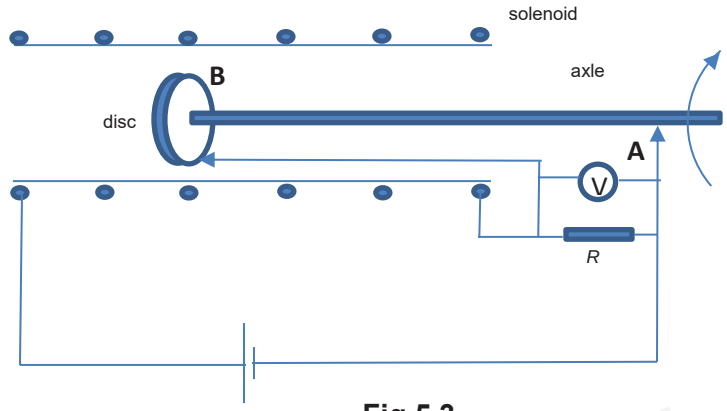

Fig.5.3

(i) Explain briefly why an emf is generated between the axle and the rim of the disc.

When the battery is switched on, there is a magnetic field generated by the solenoid. The spinning disc rim cuts through the magnetic flux lines generating a emf as suggested by Faraday's Law. [1]

The part A is connected to the axle does not cut any the magnetic flux lines as it is just spin. Therefore it is at zero potential. [1]

…… [2]

(ii) Suggest with explanation the possible outcome if terminal A is connect to the rim of the disc at point B.

There will be no readings on the voltmeter [A1] as both the terminal that is connected to the voltmeter is connected to the copper disc that is moving at the same speed. Because it is moving at the same speed the emf generated is the same and therefore no pd is observed at the voltmeter [M1]

……[2]

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3 A pulse of a radio wave lasts for 2.0×10^{-5}s. A photon of the radio wave may be considered to be at a point anywhere within this pulse, although the location of the point is not known.

Calculate

(i) the uncertainty in the position of the photon,

Since the position of the radio photon can be anywhere within the pulse

Length of pulse = uncertainty in the position = = 6.0×10^{3}m

uncertainty in the position of the photon = …….. m [1]

(ii) the uncertainty in the momentum of the photon,

$\Delta x \Delta p_x \geq \frac{\hbar}{2}$ where $\hbar = \frac{h}{2\pi}$

$\Delta p \times \Delta x \geq 5.276 \times 10^{-35}$

$\Delta p \geq 8.79x10^{-39}$

uncertainty in the momentum of the photon = …….. kgms^{-1} [2]

(ii) the uncertainty in the frequency of the photon,

$\lambda = \frac{h}{p}$

$C = f\lambda$

$\Delta f = \frac{c}{h}\Delta p$

$\Delta f = 3977 = 4000\ Hz$

uncertainty in the frequency of the photon = …….. Hz [2]

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Section B

3 (a) The internal energy of a system is defined as the sum of a random distribution of *kinetic and potential energies associated with the molecules of a system*.

(i) Comment on the "*kinetic and potential energies associated with the molecules of a system*".

Microscopic potential energy is due to the inter-molecular forces between the molecules. It depends on the phase of the system (solid, liquid or gas). [B1]
Microscopic kinetic energy is due to the random thermal motion of the molecules. [B1]

…… [2]

(ii) Hence, explain how an increase in temperature relates to an increase in internal energy.

The average microscopic kinetic energy of a system is directly proportional to the temperature of the system. [B1]
Hence, an increase in temperature would mean an increase in the average kinetic energy of the molecules and an increase in the internal energy. [B1]

…… [2]

3 (b) The effect of heating on a solid can change it into a liquid, while the heating of a liquid can change it into a gas.

(i) Define the specific latent heat of a body.

The specific latent heat of a substance is defined as the amount of thermal energy required to convert 1 kg of a substance to another phase (or state) without a change in temperature.

…….. [1]

(ii) Hence, explain why the latent heat of vaporisation is greater than the latent heat of fusion.

Energy is needed to do work against the atmosphere. [B1]
Difference in potential energies between molecules in the liquid state and gaseous state is larger than between solid and liquid state. [B1]

…… [2]

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(c) A cup of hot coffee purchased from the school canteen has a temperature of 85°C. In order to drink the 250 g beverage before Physics lecture, a student placed five ice cubes, at – 7.0°C, of mass 5.0 g each, into the coffee. In order to speed up the rate of heat transfer, the student decided to stir the drink.

The following information is given:
latent heat of fusion of ice = 334 000 J kg^{-1}
specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific heat capacity of coffee = 4300 J kg^{-1} K^{-1}

(i) Estimate the final temperature of the drink when all the ice has melted.

$$m_{ICE}c_{ICE}(0-(-7))+m_{ICE}L_{ICE}+m_{WATER}c_{WATER}(T-0)=m_{COFFEE}c_{COFFEE}(85-T)$$

$$(5\times5\times10^{-3})(2100)(7)+(5\times5\times10^{-3})(334\times10^{3})+(5\times5\times10^{-3})(4200)(T)$$

[M1]

$$=(250\times10^{-3})(4300)(85-T)$$

$$367.5+8350+105T=91375-1075T$$ [M1]

$$1180T=82657.5$$

$$T=70°C\ (2\ s.f.)$$ [A1]

[3]

(ii) State 2 valid assumptions that you have made in your calculation.

The specific heat capacity of the stirrer/cup is not taken into consideration.
No heat loss from the coffee except to the ice cubes.

heat lost due to evaporation is negligible.

……

…… [2]

(d) A cube of volume V contains N molecules of an ideal gas. Each molecule has a component v_X of velocity perpendicular to one side W of the cube, as shown in Fig. 1.1.

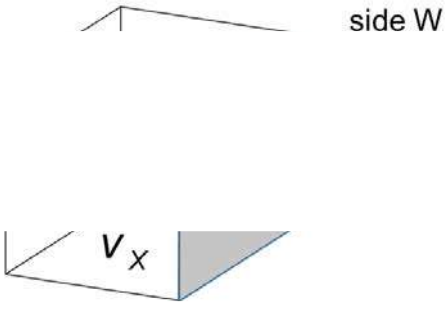

Fig. 1.1

The pressure p of the gas due to the component v_X of velocity is given by the expression

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$$pV = Nm\langle v_x^2 \rangle$$

where m is the mass of a molecule.

Explain how the expression leads to the relation

$$pV = \frac{1}{3}Nm\langle v^2 \rangle$$

where $\langle v^2 \rangle$ is the mean square speed of the molecules.

molecule has component of velocity in three directions	B1
random motion and averaging	B1
$\langle c^2 \rangle = \langle c_x^2 \rangle + \langle c_y^2 \rangle + \langle c_z^2 \rangle = 3\langle c_x^2 \rangle$	B1
so, $pV = \frac{1}{3}Nm\langle c^2 \rangle$	A0

……

……

……... [3]

(e) When air is pumped into a canister rapidly, the adiabatic process can be represented by the line with an arrow as shown in Fig. 1.2.

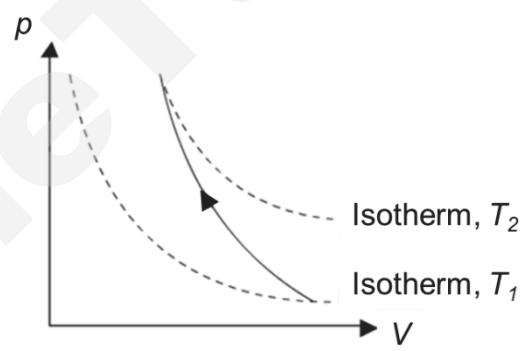

Fig. 1.2

(i) Explain how can this type of change be achieved. [2]

Using 1st law of thermodynamics
$\Delta U = Q + W$ [M1]
$\Delta U = 0 + W$ since Q = 0
$\Delta U = W$, increase in internal energy is due to work done on gas [B1]

(ii) State two conditions that could have made this process possible.

……..

……..

The canister is insulated [B1]

The change in pressure and volume occur faster than the exchange of heat [B1]

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			.....
			..... [2]
		(iii)	Hence, comment on the temperature of the air, T_2, after pumping.
			.....
			.....
			..... [1]

$T_2 > T_1$ [B1]

4 **(a)** **(i)** A doubles back, either side
B carries on, slightly deflected
C carries straight on
all 3 correct 2 marks, 1 wrong minus 1

(ii) nucleus is small in comparison to size of atom

(iii) nucleus is massive/heavy/dense B1
and positively charged B1

(b) **(i)** 1. $F = GM_1M_2/R^2$
force = $\{6.67 \times 10^{-11} \times 197 \times 4 \times (1.66 \times 10^{-27})^2\} / (9.6 \times 10^{-15})^2$
$= 1.57 \times 10^{-33}$ N

2. $F = Q_1Q_2/(4\pi\varepsilon_0R^2)$
force = $79 \times 2 \times (1.6 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (9.6 \times 10^{-15})^2]$
= 395 N

(ii) electric force >> gravitational force

(iii) loss in KE = gain in EPE
4.6 MeV = $7.36 \times 10^{-13} = Q_1Q_2 / 4\pi\varepsilon_0R$
r = 4.94×10^{-14} m

(iv) not enough energy to get close to the nucleus

(c) **(i)** $(5 \times 10^{-3}) / 226 \times (6.02 \times 10^{23})$ M1

(ii) $t_{½} = (1.60 \times 10^3 \text{ years})(365)(24)(60)(60)$ C1
$A = \lambda N$ C1
$A = (\ln 2 / t_{½}) N = 1.83 \times 10^8$ Bq A1

(iii) $A = A_0 e^{-\lambda t}$ C1
$\ln 0.90 = -\lambda t$
t = 243 years A1

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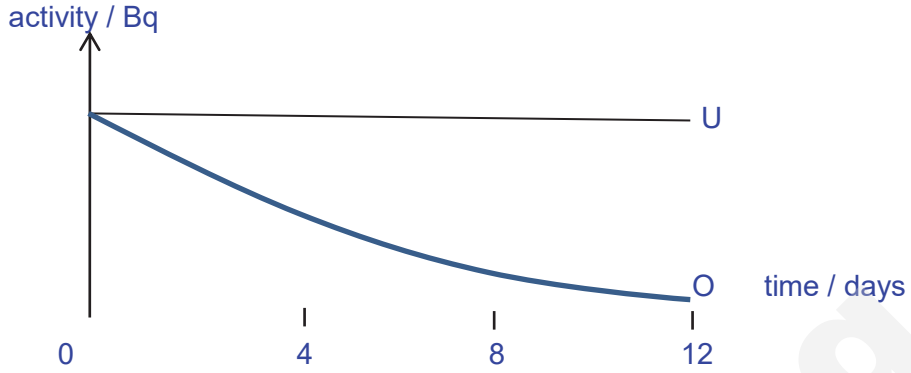
(iv)



horizontal line for U
decay curve for O

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIM EXAMINATIONS 2

H2 PHYSICS 9749
PAPER 4
28 AUG 2017

2 HRS 30 MIN

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CLASS 6 ( )

INDEX NO. _____

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, class and index number above.

Candidates answer on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

SHIFT	
LABORATORY	
FOR EXAMINERS' USE	
1	/15
2	/ 8
3	/ 20
4	/ 12
TOTAL	/ 55

This document consists of 14 printed pages.

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1 This investigation considers the time required to discharge a capacitor. Capacitors accumulate charge from a source of e.m.f., and discharges over a period of time when connected to a load.

(a) You are given a capacitor, a resistor of resistance r, a 2.00 V battery, a switch, an analog voltmeter and a digital multimeter that has been set to measure current in microamperes. The terminal of the capacitor labelled as "+" must be connected to the positive terminal of the battery, as shown in Fig. 1.1.

Using the digital multimeter as a microammeter (μA), set up the circuit as shown in Fig. 1.1.

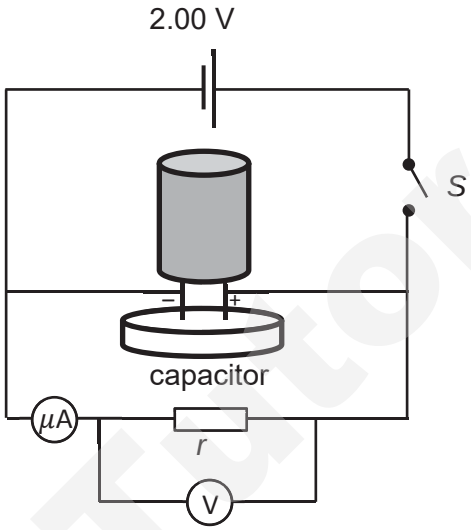

Fig. 1.1

(i) Close switch S.

(ii) The current through the ammeter will increase for a very short period of time. Measure and record the magnitude of the maximum current I_0 passing through the ammeter when the current stops increasing.
Expect 500+ μA for 2 V, 1000 μA for 4 V.
Record to 3-4 s.f.
Correct unit (μA or A)

I_0 = ... [1]

(iii) Record the reading on the voltmeter V_0.
Not graded but d.p. here will be used in part (iv)

V_0 = ...

(iv) Open switch S.

(v) Given that $V_0 = I_0 r_{eff}$, calculate the effective resistance r_{eff} of the resistor and voltmeter in parallel.
Expected values range from 3500 – 3900 Ω.
Follow smallest s.f. based on parts (ii) and (iii)
Correct method ($r = E/I_0$)
Correct units (Ω)

r = ... [1]

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(b) **(i)** Close switch S.

(ii) When the ammeter reading is equal to I_0, open switch *S* and start the stopwatch.

(iii) Record the time *T* taken for the ammeter reading to fall from I_0 to $I_0/2$.

Sample data (if different R is used will vary):

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	t_{avr}:
11.1	11.0	11.1	11.2	10.7	11.0

1-2 d.p. both accepted *[but 1 d.p. more appropriate – see part (iv)]*

Correct unit (seconds)

(iv) Estimate the percentage uncertainty in your value of *T* in **(b)(iii)**.

Uncertainty should be on the scale of 0.2 - 0.8 s: human reaction time and sampling rate of meter.

Sample values:

t	Δt	% uncertainty
10.5	0.5	4.8
11.5	0.2	1.7

Correct method (Δt/t × 100% = ____ %)

To 2 s.f. max

(c) **(i)** Close switch *S*.

(ii) When the ammeter reading is equal to I_0, open switch *S* and start the stopwatch.

(iii) At time *T* as found in **(b)(iii)**, measure and record V_T, the voltage across the resistor at that instant.

Tested values range from 0.9 – 1.0 V.

Record to 1 d.p.

Correct unit (V)

(iv) Using the values obtained above, determine the resistance r_T of the system at time *T*. Show your working clearly.

Sample values:

$I_0/2$	V_T	R_{eff}
269	1.0	3700
270	0.9	3300

Expect a range of values between 3300 – 4000.

Correct calculation method.

1 or 2 s.f. following part (iii)

Correct units (Ω)

(d) In another similar setup, the resistor is replaced with a light bulb. When V_0 was applied across the light bulb and voltmeter, the current I_0 passing through the light bulb was found to be 0.400 A.

Use your **results to predict the current $I_{1/2}$ that passes** through the light bulb when the **voltage across the light bulb and voltmeter is** equal to $V_0/2$.

- If (c)(iii) is exactly $v_0/2$ (or student says "approximately equal to"), allow $I_{1/2} = I_0/2$ directly.
- If student uses V=IR with same R for both, the value in (a)(v) must be same as the value in (c)(iv) (or student says approx.)
- If neither of the above, student should use ratios or other appropriate method, e.g. "when current half, V =, so when V half…"
- ***Theory should not be used.***

(e) It is suggested that the **time** $t_{1/2}$ required for the current passing through the ammeter to decrease to half its initial value is directly proportional to the **effective resistance** *R*, and is not affected by the magnitude of the **e.m.f.**

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provided.

Making use of the additional accumulator and resistor, take further measurements to investigate this suggestion.

State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

Varying resistance while keeping emf constant. Possible methods: • Another resistor in series/parallel • Removing voltmeter from circuit/placing voltmeter in series
Either **correct calculation** of ***effective*** resistance using voltage and current, or realizing that voltmeter affects effective resistance and removing voltmeter from circuit. If working not shown (e.g. showing values of R without showing current) mark not given
Conclusion based on ***quantitative*** data from varying resistance. Should be less than 10%, also accept if student says >5% so not proportional.
Varying emf while keeping resistance constant. Possible methods: • Adding second battery • Using potential divider with the other resistor
Conclusion based on ***quantitative*** data from varying emf. Possible evidence: • Compare two cases where only e.m.f. differs. Show that time is approximately constant ***(ideally within human reaction time or experimental error)*** • Have more than two cases with different R and e.m.f. (e.g. 3 – 4 cases which vary R, emf or both), and show that the proportionality constant between R and T are same for all.

Summary of sample data:

Reff /Ω:	t_{avr} /s:	V /V
4555.809	13.48	2
2721.088	8.846667	2
19230.77	56.65	2
4889.976	14.62	2

Reff /Ω:	t_{avr} /s:	V /V
9718.173	29.11	2
3741.815	11.59667	4
3717.472	11.024	2
3525.046	11.024	2

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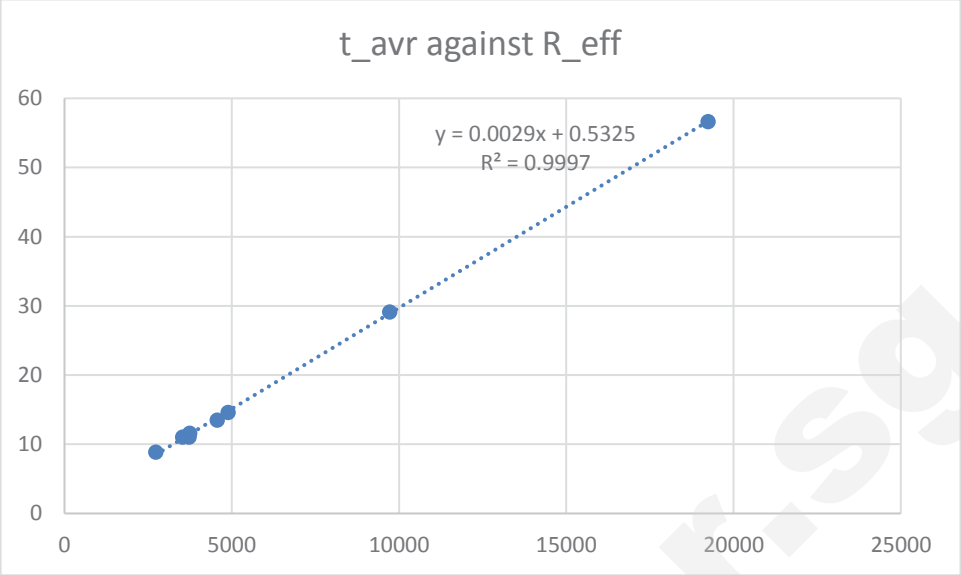

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(f) One common application of such circuits is to power the bright flashes used in photography. Connecting a capacitor to a battery allows it to charge up, and when connected to a load such as a camera flash, it discharges by releases energy over a certain length of time. Outdoor photographers may find that the camera flash functions differently during extremely cold winters.

Suggest one change that could be made to this investigation in Singapore to safely study how the discharge time changes at different temperatures. State any relevant precautions or steps taken to quantify this change.

Student states method for changing temperature of entire circuit or relevant components.

Possible answers: Immerse in ice bath, use cold pack, place in freezer while putting measuring devices outside, use room with air conditioning or cold storage rooms, etc.

Precautions:

EITHER

Student states precautions taken to avoid short-circuiting.
Possible answers: Seal in air-tight bag, use of cold pack instead of ice, only insert relevant components into ice bath, etc

OR

Student states precautions taken regarding cold injuries.
Possible answers: Appropriate gloves/winter wear

OR

Student states other relevant consideration

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Student states suitable method for measuring the temperature.

Experimental setup	Appropriate methods for measurement
Immerse in ice bath	Measure temperature of water (e.g. with thermometer or thermocouple)
Use cold pack	Touch thermocouple directly to circuit; use infrared thermometer.
Put in freezer or air-conditioned room (or similar method of changing ambient temperature)	Award a mark for a suitable method of measuring air temperature inside the freezer.

Students who design an experiment using a camera or describe flashes or other lights will lose marks due to not reading the question. Students who replace resistor with thermistor will also be penalized.

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2 In this experiment, you will investigate how the heating of a mass of boiling water is affected by the addition of metal mass of a different temperature.

(a) (i) Set up the apparatus as shown in Fig. 2.1.

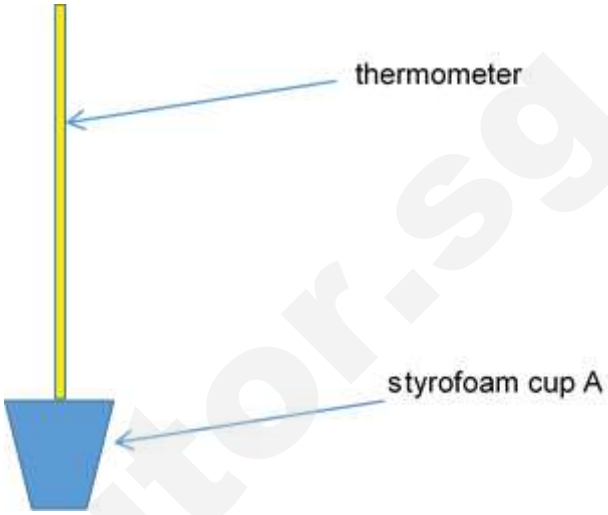

Fig. 2.1

Using a measuring cylinder, fill up styrofoam cup A with tap water with 100 cm^3 of tap water.

Measure the temperature of the water, t_o.

t_o = 28.0 °C

(ii) Fill styrofoam cup B with hot water (55 °C > t_h > 90 °C) and place the 100 g mass provided in it. Wait for the temperature to stabilise.

Measure the temperature of the hot water with mass, t_h.

correct unit
correct precision
between 55 °C > t_h > 90 °C

t_h = 86.0 °C [1]

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(iii) With a string, transfer the 100 g mass from the cup B to cup A.
Wait for the temperature of cup A to stabilise.
Measure the final temperature of the water and masses, T.
Remove the mass and pour away the water in cup A.

correct unit
correct precision
> t_o °C

T = ... 33.0 °C [1]

(b) Repeat **(a)** for different values of temperature between 55 °C and 90 °C for t_1 for the given mass.

Complete Fig. 2.2.

t_o / °C	t_h / °C	T/ °C	$(T - t_o)$ / °C	$(t_h - T)$ / °C
28.0	86.0	33.0	5.0	53.0
28.0	75.0	32.5	4.5	42.5
28.0	69.0	32.0	4.0	37.0
28.0	66.0	31.0	3.0	35.0
28.0	61.0	30.0	2.0	31.0
28.0	57.5	29.5	1.5	28.0

Fig. 2.2

[2]

All 6 values of T taken successfully, $(T - t_o)$ and $(t_h - T)$ *decrease as* t_h *decreases* [1]

All temperature values calculated correctly and appropriate s.f. [1]

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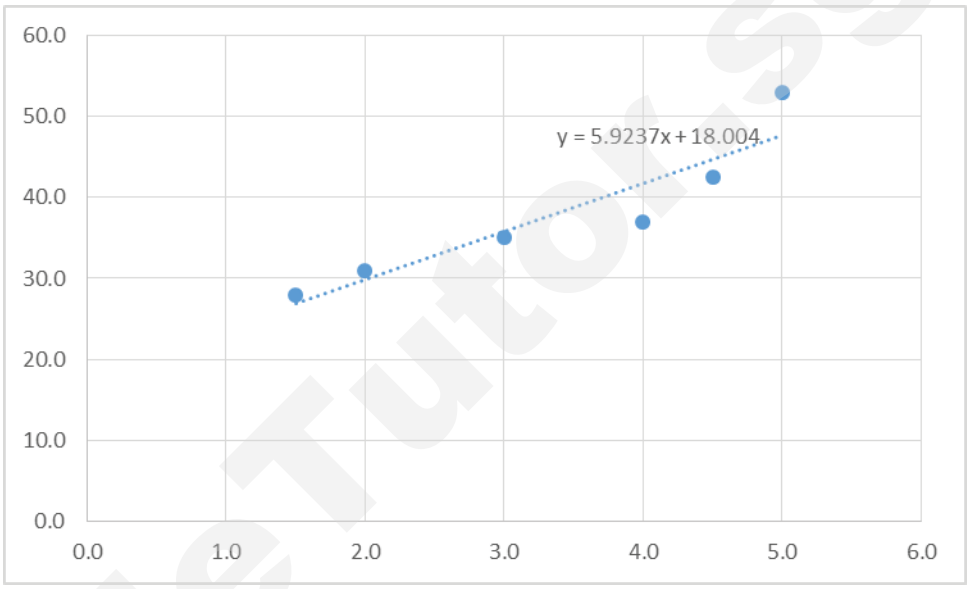
(c) It is suggested that the relationship between temperature increase $(T - t_o)$ in cup A and temperature decrease of the mass is related by

$$t_h - T = k\,(T - t_o)$$

where k is a constant.

(i) Using your data in Fig. 2.2, plot $(t_h - T)$ against $(T - t_o)$, in Fig. 2.3.

$(t_h - T)$ / °C



$(T - t_o)$ / °C

[2]

(ii) Hence determine the gradient of the plotted graph in Fig. 2.3.

Gradient = 5.92 [Correct Calculation of gradient

No units

gradient = ... [1]

(d) Describe **one source of uncertainty or limitation of the** procedure for this experiment.

.....

Extra amount of water in the cup and during transfer.
Water stick the the mass when transfer.

..... [1]

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3 In this experiment, you will investigate the length of a loaded spring as the load is varied.

(a) Measure and record the length *L* of the metal rod.

99.9 cm

L = ...

(b) **(i)** Support the rod as shown in Fig. 3.1

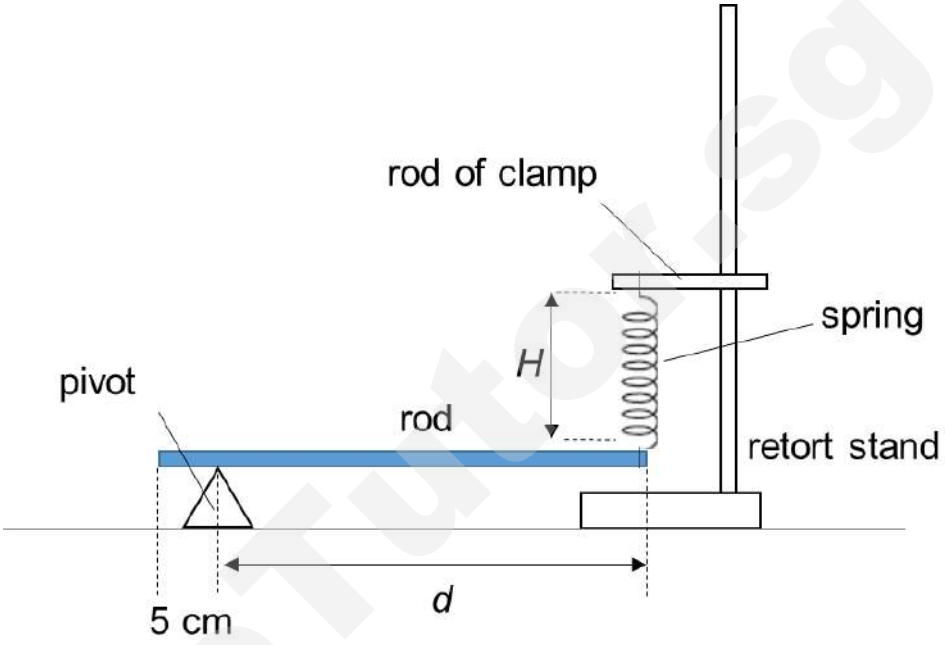

Fig. 3.1

(ii) Adjust the position of the pivot so that it is approximately 5 cm from the free end of the rod.

(iii) Adjust the clamp so that the rod is horizontal and the spring is vertical.

(c) **(i)** Measure and record the length *H* of the coiled part of the spring and the distance *d* from the pivot to the point where the spring is hooked to the rod.

Correct d.p
Correct unit

8.5 cm

H = ... [1]

94.0 cm

d = ...

(ii) Estimate the percentage uncertainty in your value of *H.*

ΔH ≥ 0.2 mm
Correct s.f.
Correct calculation

percentage uncertainty = ... [1]

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(d) Repeat (b)(ii), (b)(iii) and (c)(i) to obtain further sets of readings for *d* and *H*.

d / m	*H* / m	1/*d* / m^{-1}
0.940	0.085	1.06
0.900	0.080	1.11
0.850	0.075	1.18
0.800	0.070	1.25
0.750	0.065	1.33
0.700	0.058	1.43
0.650	0.050	1.54
0.600	0.042	1.67
0.550	0.032	1.82

[1] Raw data: to correct precision of metre rule
[1] Processed value: to correct s.f. based on raw data
[1] Range of d ≥ 20 cm, d > 40 cm
[1] Layout: column headings (raw data and calculated quantities: *(d, H, 1/d)*. Each column heading must contain a quantity and unit as shown.
[2] Award 2 marks if candidate has successfully collected 6 or more sets of data *((d, H)* without assistance or intervention.
Award 1 mark if candidate has successfully collected 5 sets of data *((d, H)* without assistance/intervention.
Award zero mark if candidate has successfully collected 4 or fewer sets of data *(d, H)* without assistance/intervention.
Deduct 1 mark if candidate requires some assistance/intervention but has been able to do most of the work independently.
Deduct 2 marks if candidate has been unable to collect data

[6]

(e) Theory suggests that *d* and *H* are related by the equation

$$H = z\left(\frac{W}{k}\right)\left(\frac{1}{d}\right) + \left(\frac{W}{k}\right)$$

where *W* is the weight of the rod, *k* is the spring constant of the spring and *z* are constants.

Plot a suitable graph to determine *W* and *z*.

[1] Linearising equation
[1] Gradient - the hypotenuse of the Δ must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square.
[1] Value of W calculated correctly and with correct units.
[1] Value of z calculated correctly and with correct units.

$$Fd = W\left(d - \frac{L}{2}\right)$$

$$h = \frac{A}{d} + B$$

$$h = z\left(\frac{W}{k}\right)\left(\frac{1}{d}\right) + B$$

actual mass of rod =	330 g =	0.330	kg
y-intercept =		0.157	= W/k
W =		3.611	
convert to mass =		0.368	kg
grad =	-0.0691	= z(W/k)	
therefore z =		-0.44013	

Physical meaning of z is half the length of the uniform rod or position of the c.g. of the rod w.r.t. to one end.

z = …… [4]

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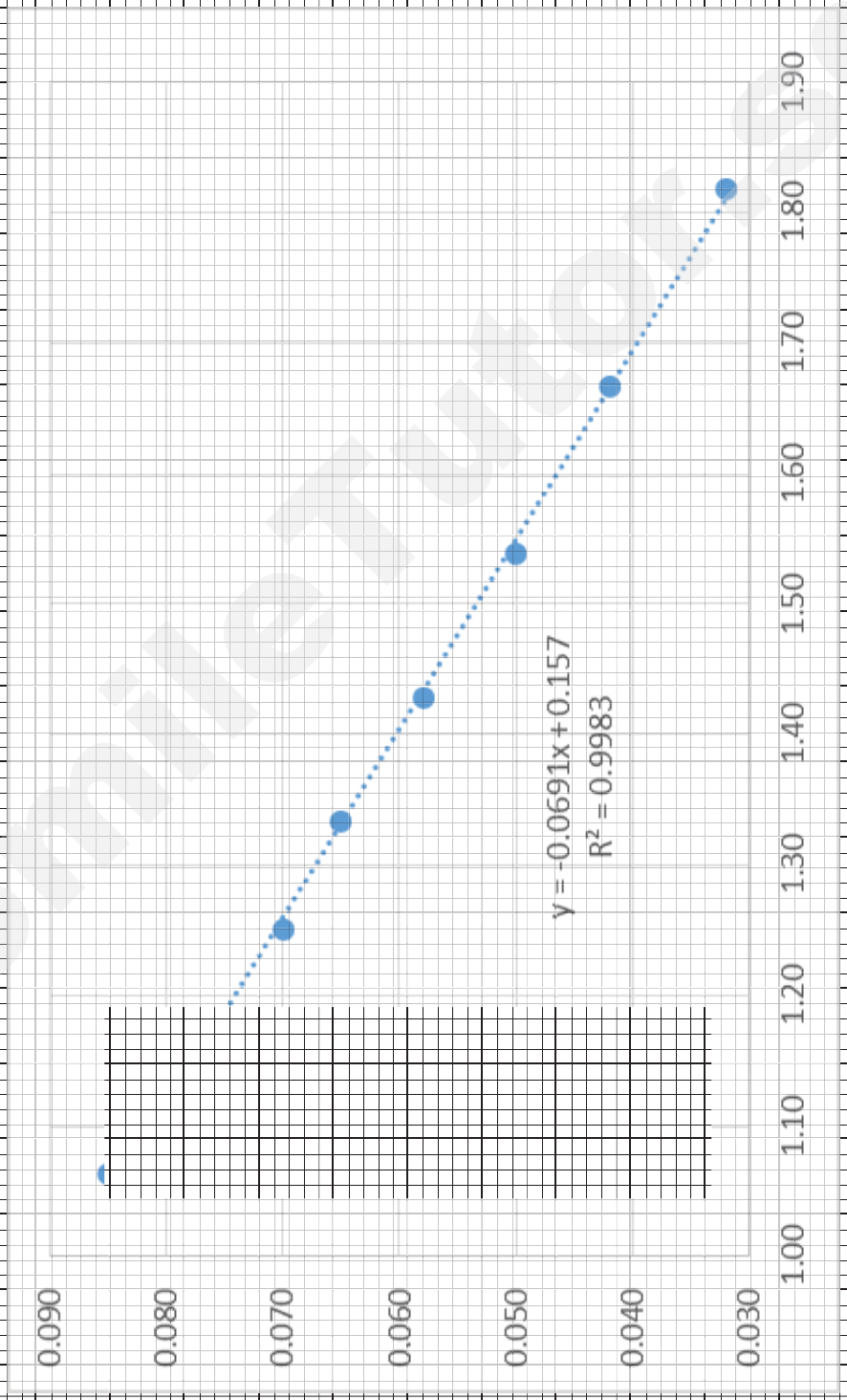
For graph:
[1] Sensible scales must be used. Awkward scales (e.g. 3:10) and numbering are not allowed. Scales must be chosen so that plotted points occupy at least half the graph grid in both x and y directions. Axes must be labelled with the quantity which is being plotted.
[1] All observations must be plotted. Work to an accuracy of half a small square.
[1] Straight line of best fit - judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.

[3]



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(f) Suggest a physical meaning for the constant z.

z is half the length (or position of the c.g. from one end) of the metal rod.

..... [1]

(g) Comment on any anomalous data or results that you may have obtained. Explain your answer.

There are no anomalous data as all points follow the trend of the best fit line.

or

There is an anomalous data as it lies relatively far from the best fit line as compared to the other points. [1]

(h) **(i)** State one significant sources of error in this experiment.

It is difficult to measure the value of H without disturbing the equilibrium of the system.

It is difficult to manually hold the metre rule to stably measure the value of H. [1]

(ii) Suggest an improvement that could be made to the experiment to address the source of error identified in **(h)(i).** You may suggest the use of other apparatus or a different procedure.

Use a light fiducial marker attached to the end of the spring, to assist in the reading-off from the metre rule.

Use a retort stand and clamp to secure the metre rule vertically to enable a stable reading-off.

..... [1]

(i) Sketch another line on your graph to represent an experiment performed with a heavier rod. Label this graph **Q**.

[1]

Heavier rod → W larger

Hence, **Q** will have steeper gradient and larger vertical intercept

[Total: 20 marks]

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4 Beta particles can be deflected by magnetic fields.

Design a laboratory experiment to investigate how the magnetic flux density *B* of a magnetic field affects the angle θ through which beta particles are deflected when they pass through a uniform magnetic field.

The only radioactive source that is available to you emits α, β and γ radiation.

You should draw a diagram showing the arrangement of your apparatus. In your account you should pay particular attention to

(a) the procedure to be followed,
(b) the method by which beta particles **only** would be detected,
(c) the method of measuring the angle of deflection,
(d) how the magnetic field would be produced, measured and changed,
(e) any reliability and safety precautions you would take.

Diagram

	marking scheme	
	DESIGN	
A1	Sensible choice of equipment and basic idea OK Source / magnetic field / detector Inappropriate choice of apparatus cannot score this mark. Ignore lead or aluminium plates at this stage.	1
A2	Method of measuring angle of deflection (e.g. detector at edge of large protractor / lengths & trig ratio used) Do not allow vague 'use a protractor'. This mark can be awarded even if the detector has not been specified.	1
A3	Use Hall probe / search coil / current balance to measure field strength Allow Helmholtz coils expression if Helmholtz coils used. (see below) Allow a current or voltage measurement as indication of field strength (as $I \alpha B$)	1
	PROCEDURE	
B1	Method of removing α radiation or statement that α radiation almost undeflected Use paper or distance to detector > few cm/air to absorb alpha Could be shown on the diagram. Do not allow lead / aluminium plate. Allow α to be shown deflecting in the opposite direction to β on the diagram.	1
B2	γ-radiation undeflected / deflect beta particles using electric field Can be shown on diagram. Do not allow 'absorb gamma with lead plate'.	1
B3	Method of changing field strength. Do not allow changing magnets of different strengths. Do not allow changing number of coils.	1
B4	Workable procedure for uniform fields Measure deflection and field strength; change current in coils and repeat.	1

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	SAFETY and ANALYSIS	
C1	Any two safety precautions e.g. use source handling tool store source in lead lined box when not in use do not point source at people/do not look directly at source place lead sheet at 'end of experiment' to absorb unwanted rays	1
C2	Plot graph of lg θ against lg B	1
	DETAIL	
D1/2	Any good/further detail. Examples of creditworthy points might be: Type of detector (GM tube/film/screen/scintillation counter). N/A cloud chamber/CRO Repeat readings to allow for randomness of activity Correct deflection of beta on diagram/left hand rule ideas (diagram or written) Separation of coils = radius of coils for uniform field Discussion of count rate (and not just count) Plane of semiconductor slice is perpendicular to field lines Calibrate Hall probe Detail of calibration Collimation ideas (*collimate: to make parallel; line up*) Allow other valid points. Any three, one mark each. B1 = B2 = B4 = 0 if lead or aluminium plate is placed in front of the source. Allow thin (less than 1 mm) sheet or foil	3

*UNDERLINING
In the marking scheme, underlining indicates information that is essential for marks to be awarded.

.....

.....

.....

.....

.....

.....

.....

[Total: 12 marks]

END OF PAPER

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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME			
CG		**INDEX NO.**	

PHYSICS 9749/01

Preliminary Examination **21st Sep 2017**
Paper 1 Multiple Choice **1 hour**

Additional Materials: OMS.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in soft pencil on the OMS.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

.

For Examiners' Use	
MCQ	/ 30

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DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer all questions.

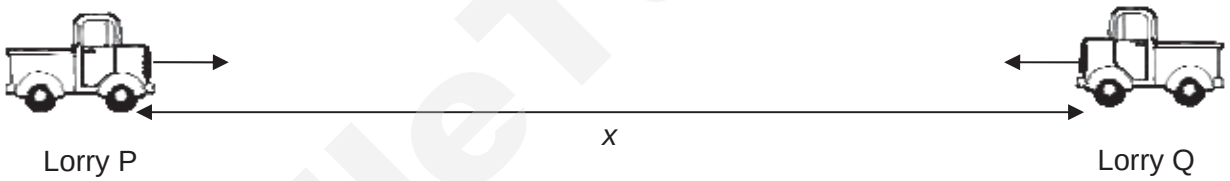
1 Four students conducted an experiment to determine the value of g, acceleration of free fall. The values obtained by the students are as shown in the table.

Student	g_1 / m s^{-2}	g_2 / m s^{-2}	g_3 / m s^{-2}	g_4 / m s^{-2}
P	9.40	9.80	9.55	9.65
Q	9.80	9.60	9.90	10.06
R	10.10	9.90	10.15	9.85
S	9.45	9.48	9.52	9.55

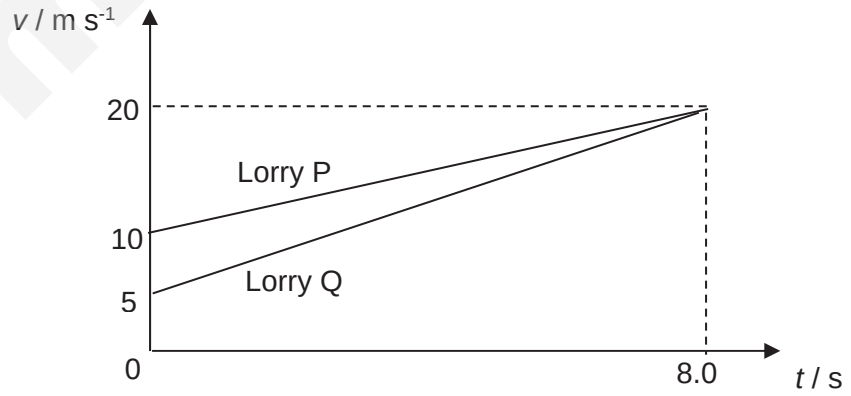
If the correct value of g is 9.82 m s^{-2}, which of the students has/have the largest systematic and random errors in their experiments ?

	Largest systematic error	Largest random error
A	Q	P
B	P	Q
C	Q	S
D	S	Q

2 Lorry P and Lorry Q are initially at a distance x metres apart and are travelling in the opposite directions as shown below.



The graph shows the variation with time t of the speeds v of Lorry P and Lorry Q respectively.



At t = 8.0 s, the two lorries are 40 m apart. What is x?

A 60 m **B** 120 m **C** 220 m **D** 260 m

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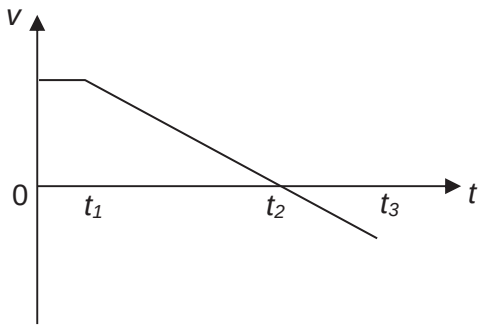
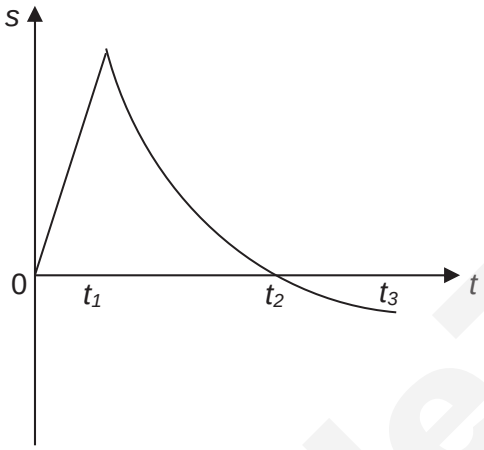
3 The graph shows how the speed v of an object varies with time t.

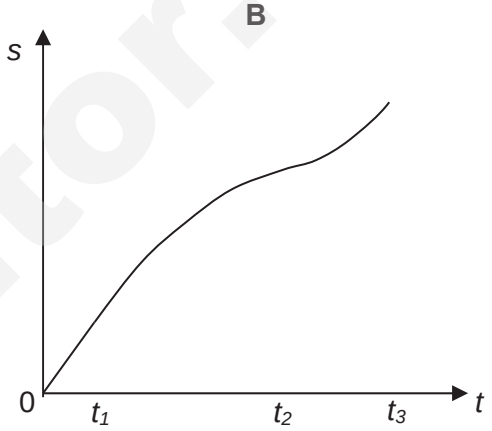


Which graph represents the variation the displacement s travelled by the object with time t?

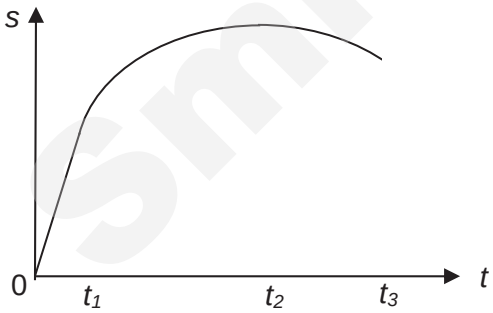
A



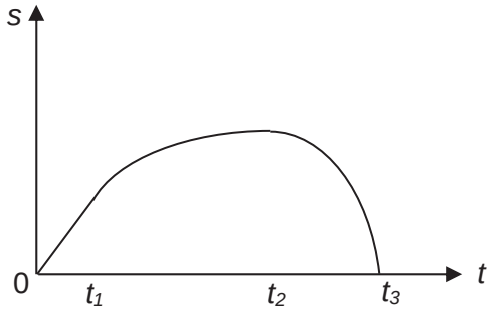
B



C



D



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4 A jet of water of density 1000 kg m^{-3} leaves the nozzle of a hose of radius 2.0×10^{-2} m. The water is directed perpendicularly to the wall at a speed of 0.50 m s^{-1}. Assume that the water does not rebound.

What is the force exerted on the wall by the water?

A 0.314 N **B** 0.628 N **C** 1.27 N **D** 15.7 N

5 An astronaut falls vertically from a space vehicle and hops on the moon. The following statements are about the forces acting while the astronaut is in contact with the surface of the moon.

Which statement is correct?

A The force that the astronaut exerts on the moon is always equal to the weight of the astronaut.
B The force that the astronaut exerts on the moon is always less than the weight of the astronaut.
C The weight of the astronaut is always equal in magnitude and opposite in direction to the force that the moon exerts on the astronaut.
D The force that the astronaut exerts on the moon is always equal in magnitude and opposite in direction to the force the moon exerts on the astronaut.

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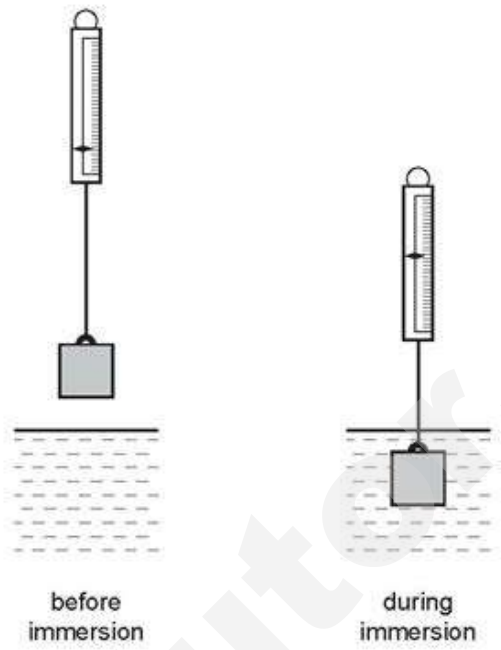
6 The diagram shows a metal cube suspended from a spring balance before and during immersion in water.

A reduction in the balance reading occurs as a consequence of the immersion.



Which statement is correct?

A The balance reading will be further reduced if the cube is lowered further into the water.

B The balance reading during immersion corresponds to the upthrust of the water on the cube.

C The forces acting on the vertical sides of the cube contribute to the change in the balance reading.

D The balance reading during immersion will be increased if the water is replaced by oil.

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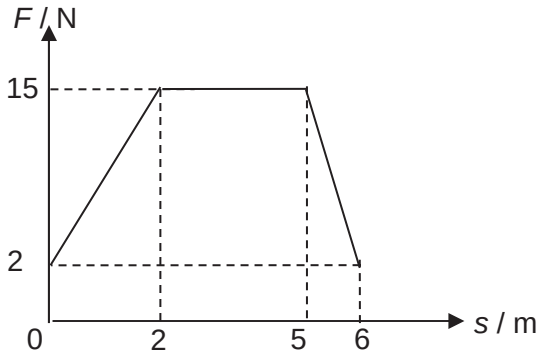
7 A student pushes a box from rest along a rough floor with constant friction of 2.0 N.

The graph shows the variation of the force exerted by the student on the box with displacement.

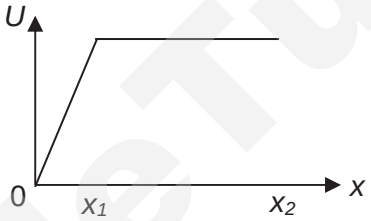


The final speed of the box after travelling 6 m is 5.0 m s^{-1}.

What is the mass of the box?

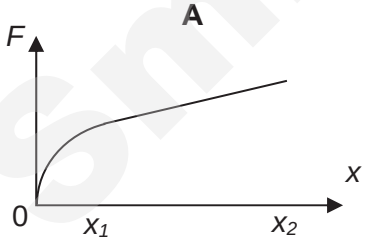
A 4.68 kg **B** 5.64 kg **C** 23.4 kg **D** 28.2 kg

8 The graph how the potential energy *U* of an object varies with displacement x.

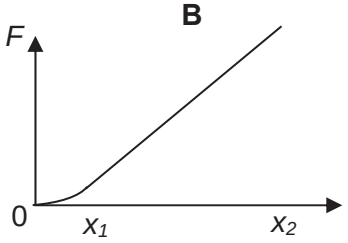


Which of the following graphs represents the variation of force acting on the object with displacement *x*?

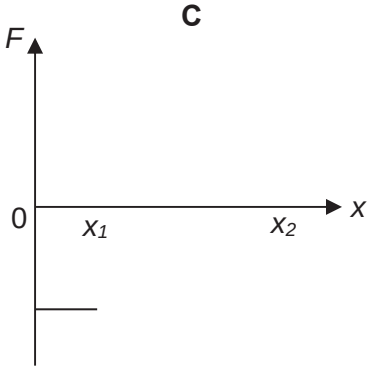
A



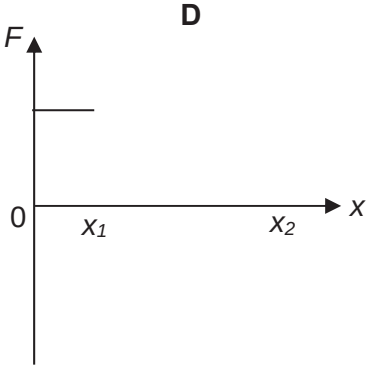
B



C



D



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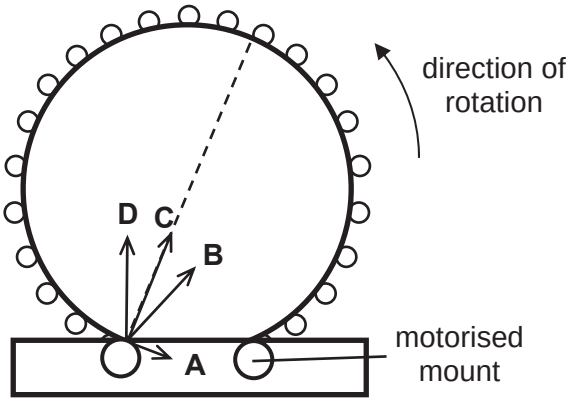
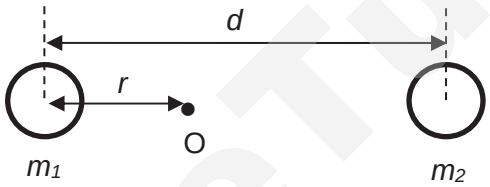
9 The Singapore Flyer wheel is supported at two points on the bottom by motorised mounts which cause it to rotate anticlockwise with constant angular velocity.



Which of the labelled arrows shows the direction of the force exerted by the motorised mount on the wheel just as it starts to turn?

10 Two planets of mass m_1 and m_2 perform circular motion about their common centre of mass O with the same angular velocity. If the mean separation between the centres of the masses is d, what is the distance from the centre of mass m_1 to the centre of mass of the system, r?



A $\frac{m_1}{m_2} d$

B $\frac{m_2}{m_1} d$

C $\frac{m_1}{m_1 + m_2} d$

D $\frac{m_2}{m_1 + m_2} d$

11 The escape speed of an oxygen molecule at the Earth's surface is 1.1×10^4 m s^{-1}.
What is the escape speed at a height of $0.2R$ above the Earth's surface, where R is the radius of the Earth?

A 0.5×10^4 m s^{-1}
B 1.0×10^4 m s^{-1}
C 1.1×10^4 m s^{-1}
D 1.2×10^4 m s^{-1}

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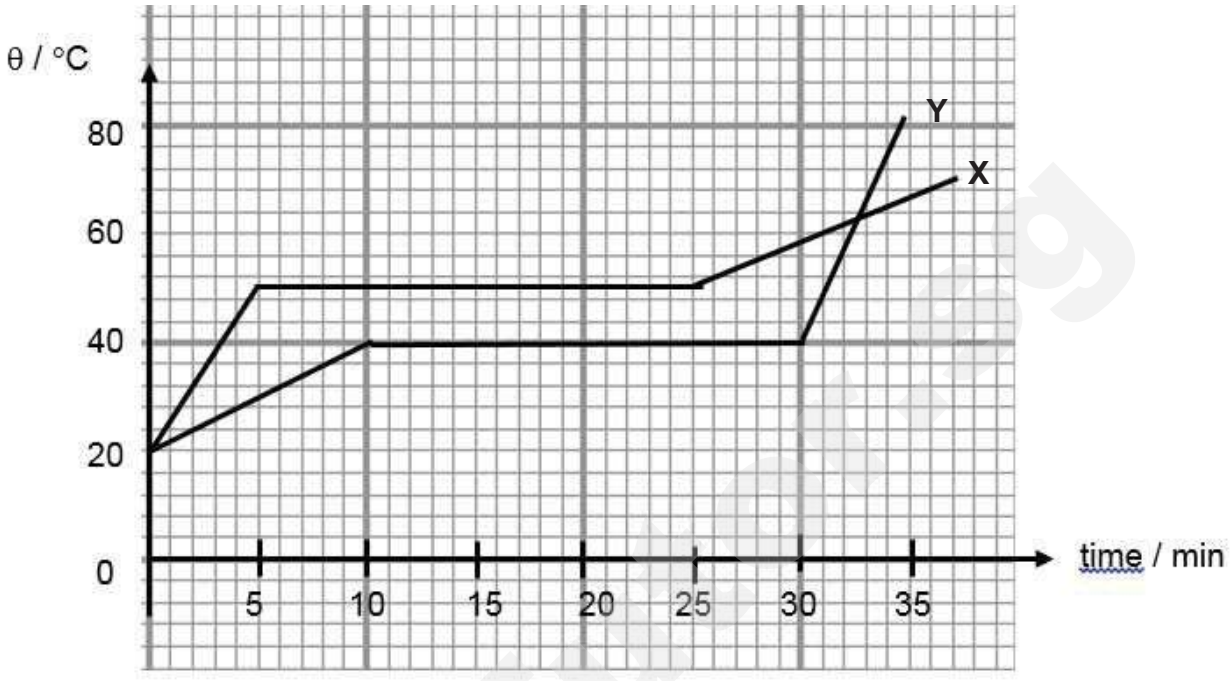
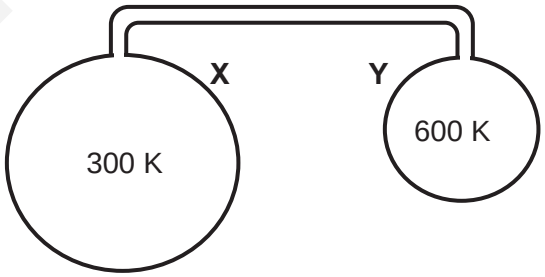
12 2.0 kg of solid X and 1.0 kg of solid Y are separately heated by two heaters of the same power. The power output of the heaters is the same throughout the whole experiment. The following graphs show the variation of the temperatures of X and Y with time.



What is the ratio of the specific heat capacity of solid X to solid Y?

A 1:3 **B** 1:6 **C** 2:3 **D** 3:2

13 The volume of Bulb X is twice that of Bulb Y. They are filled with the same ideal gas and are connected by a narrow tube, as shown. A steady state is established with Bulb X held at 300 K and Bulb Y at 600 K. If there are *n* moles of gas in Bulb X, how many moles of gas are there in Bulb Y?



A $\frac{1}{4}n$ **B** $\frac{1}{2}n$ **C** n **D** $2n$

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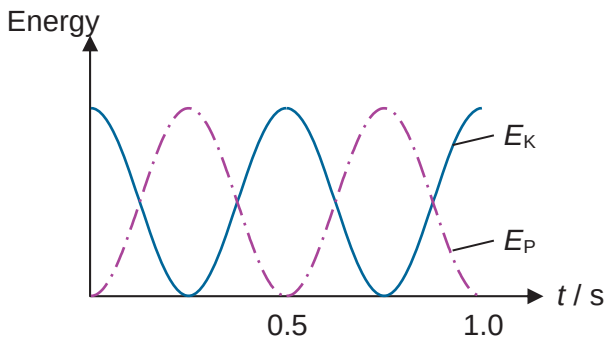
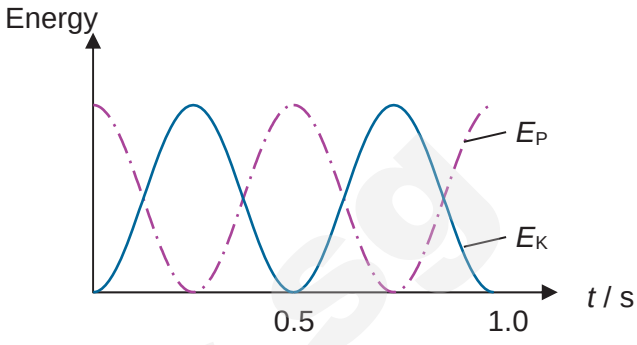
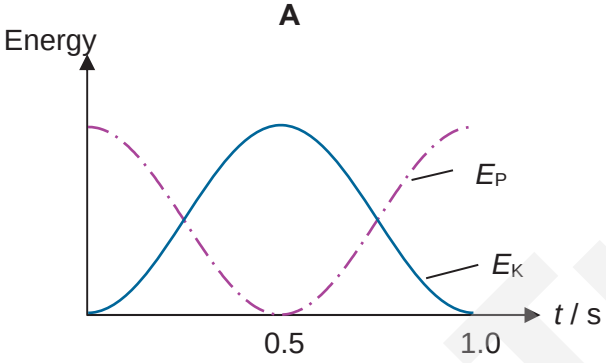
14 A certain simple pendulum swings with a period of 1.0 s. The bob of such a pendulum is given a small displacement and released at $t = 0$. Which diagram correctly shows the bob's kinetic energy E_K and its potential energy E_P varies with time?



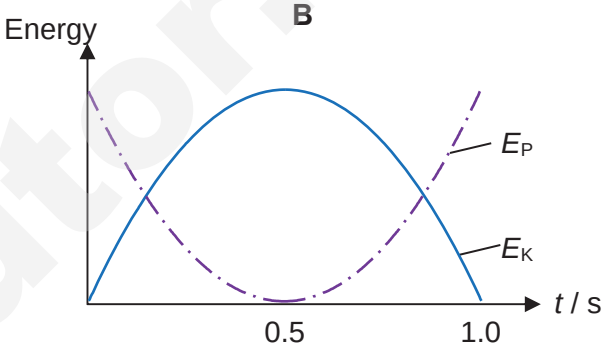
A



B



C



D

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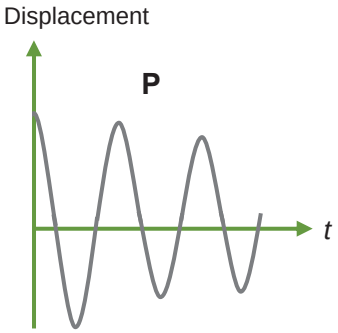
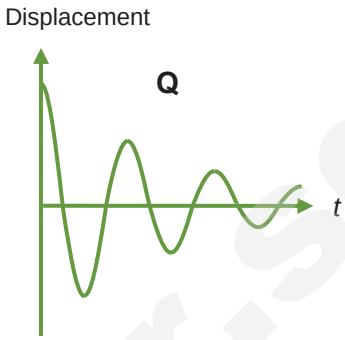
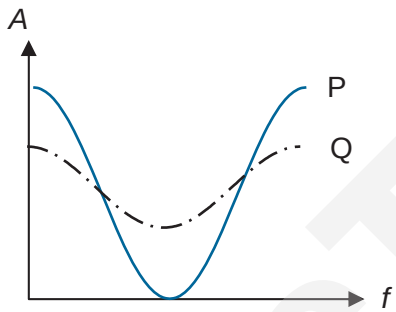
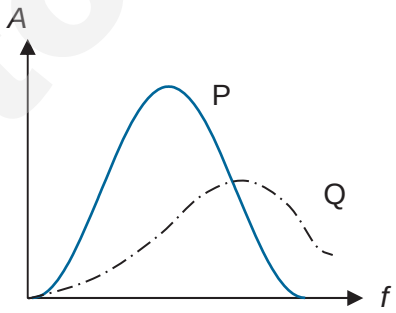
15 Two objects P and Q are given the same initial displacement and then released. The variation of their displacements with time *t* are as shown in the given graphs. The two objects are then driven by sinusoidal driving forces of the same constant amplitude and of variable frequency *f*. Which of the following graphs correctly shows how the amplitudes *A* of P and Q varies with *f* ?



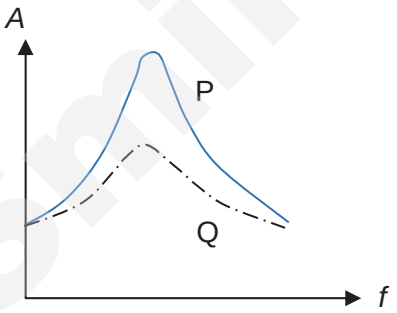




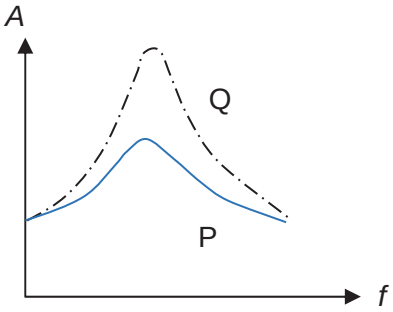
A



B



C



D

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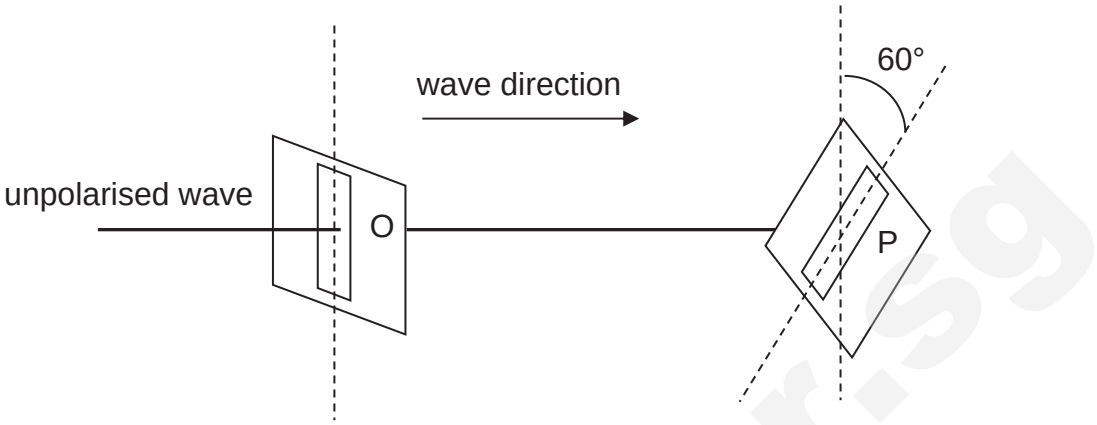
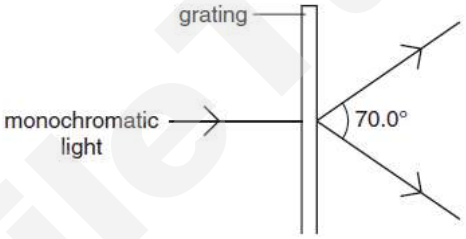
16 An unpolarised wave passes through polariser O such that the emerging wave is plane-polarized with an intensity of 2.0 W m^{-2}. A second polariser P is placed further such that the plane-polarised wave is incident normally on it. Polariser P is rotated clockwise by an angle of 60°.



What is the intensity of the wave after passing through polariser P ?

A 0.25 W m^{-2} **B** 0.5 W m^{-2} **C** 1.0 W m^{-2} **D** 2.0 W m^{-2}

17 A diffraction grating is used to measure the wavelength of monochromatic light as shown below.

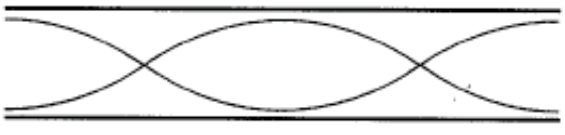


The spacing of the slits in the grating is 1.00 x 10^{-6} m. The angle between the first order diffraction maximas is 70.0°.

What is the wavelength of the light?

A 287 nm **B** 470 nm **C** 574 nm **D** 940 nm

18 A stationary wave is formed in an open tube as represented in the diagram.



How many antinodes are formed by a stationary wave of twice the frequency?

A 2 **B** 4 **C** 5 **D** 6

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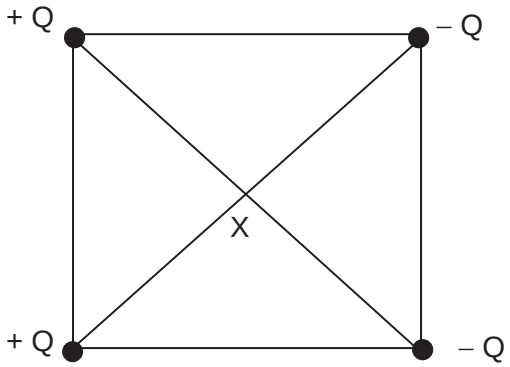
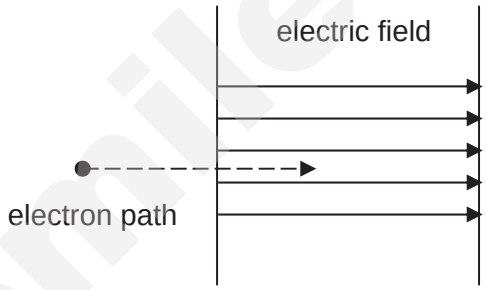
19 The diagram shows four point charges arranged in the corners of a square. What are the values of the electric field strength *E* and the electric potential *V* at a point X in the middle of the square?



	E	*V*
A	not zero	zero
B	not zero	not zero
C	zero	not zero
D	zero	zero

20 An electron has a de Broglie wavelength of 5.6×10^{-11} m. It enters an electric field with strength of 2.3×10^{4} V m^{-1} as shown.



How long will it take for the electron to stop after it enters the electric field?

A 5.0×10^{-28} s **B** 2.0×10^{-15} s **C** 3.2×10^{-9} s **D** 4.2×10^{-2} s

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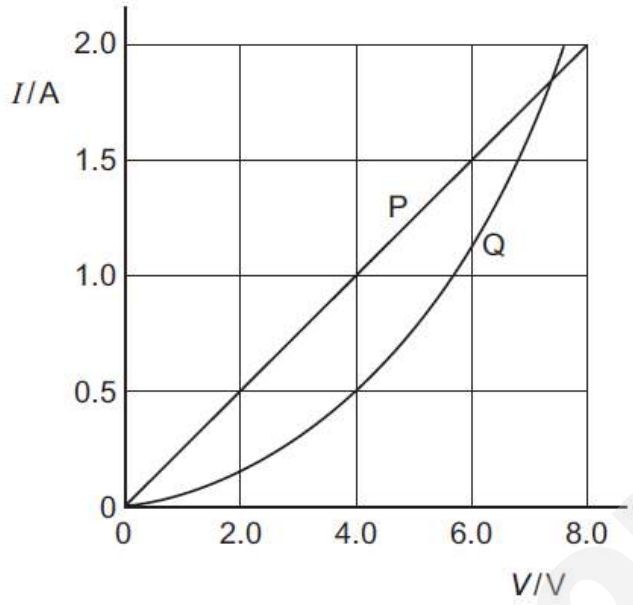
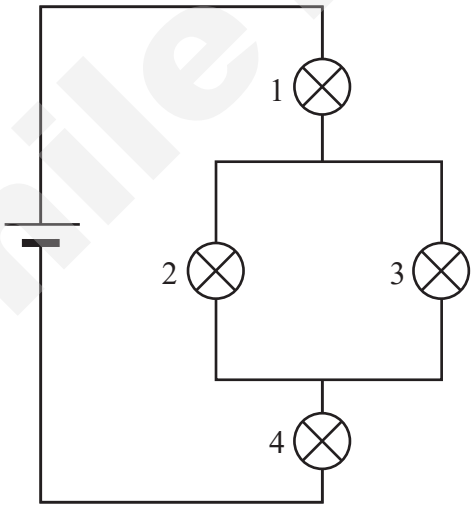
21 The I-V characteristics of two electrical components P and Q are shown below.



Which statement is correct?

A P is a resistor and Q is a filament lamp.
B The resistance of Q increases as the current in it increases.
C At 1.9 A the resistance of Q is approximately half that of P.
D At 0.5 A the power dissipated in Q is double that in P.

22 An ideal cell and four identical bulbs are connected as shown.



Bulb 3 is removed. Which of the following describes the changes in the brightness of bulbs 1, 2 and 4?

	Bulb 1	Bulb 2	Bulb 4
A	dimmer	brighter	brighter
B	dimmer	brighter	dimmer
C	brighter	dimmer	brighter
D	dimmer	dimmer	dimmer

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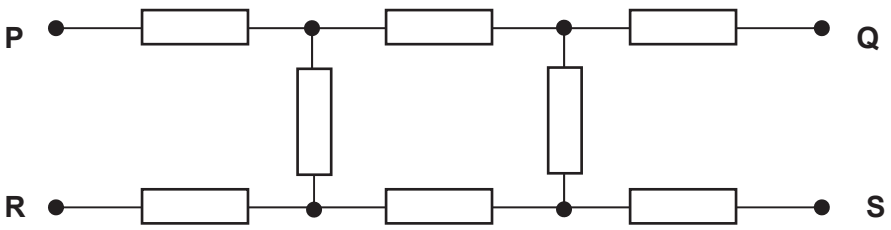
23 Each resistor has a similar resistance of 10 Ω. What is the equivalent resistance of the circuit shown in the figure below between points **P** and **S**?



A 10 Ω **B** 20 Ω **C** 30 Ω **D** 40 Ω

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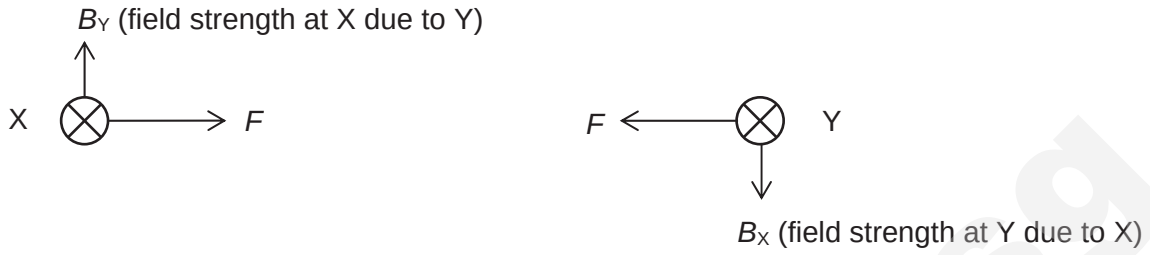
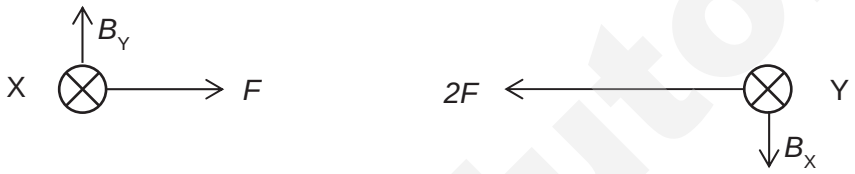
24 Two long, parallel, straight wires X and Y carry equal currents into the plane of the page as shown. The diagram shows arrows representing the magnetic field strength B at the position of each wire and the magnetic force F on each wire.



The current in wire Y is doubled. Which diagram best represents the magnetic field strengths and forces?

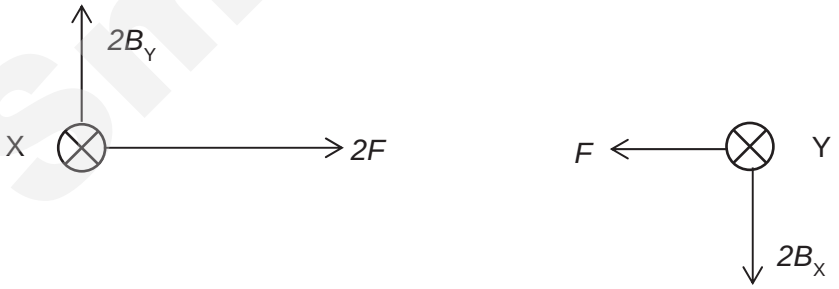
A



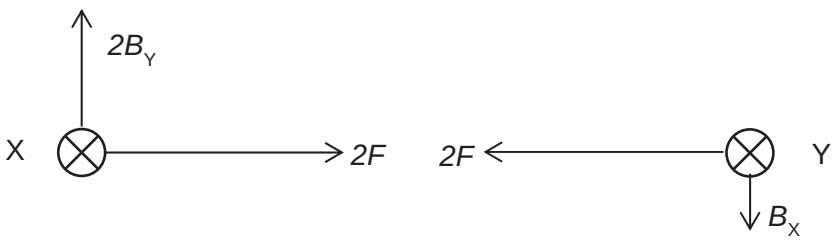
B



C



D



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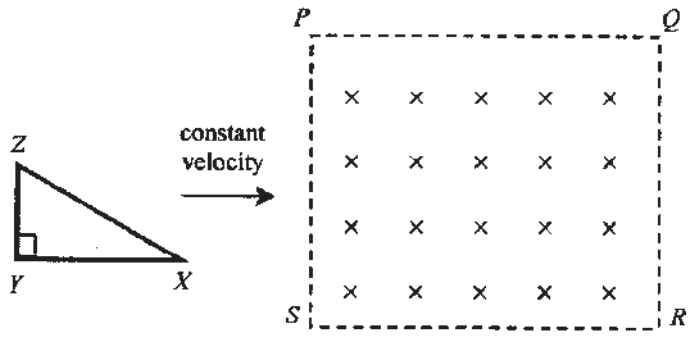
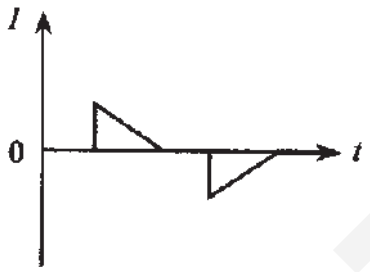
25

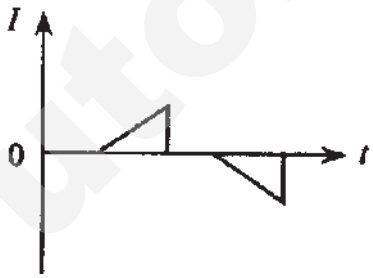


In the diagram above, *XYZ* is a small right-angled triangular metal frame moving with a constant velocity across a rectangular region *PQRS* with a uniform magnetic field pointing into the paper. Which of the following graphs best shows the variation of the current I induced in the frame with time *t*?

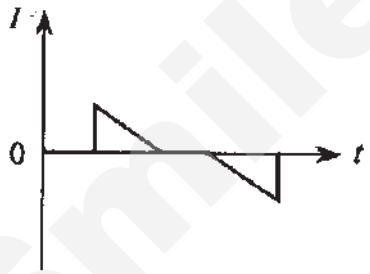
A



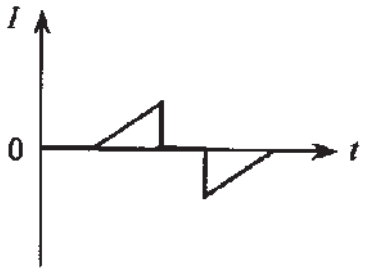
C



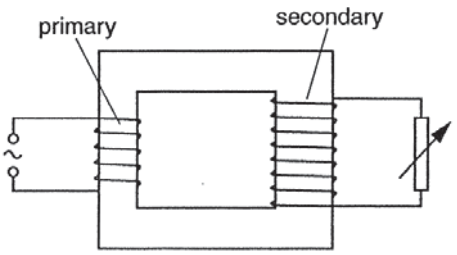
B



D



26 The primary coil of a transformer is connected to an alternating voltage supply. The secondary coil is connected across a variable resistor.



Which change will cause a decrease in the p.d. across the secondary coil?

A Increasing the number of turns of the primary coil

B Increasing the current in the primary coil

C Increasing the cross-sectional area of the secondary coil

D Increasing the resistance of the variable resistor

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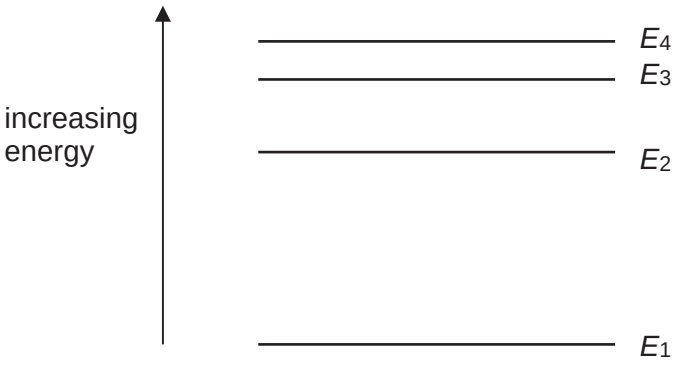
27 Some of the energy levels of the hydrogen atom are represented in simplified form by the given diagram which has a linear scale. The emission of blue light is associated with the transition of an electron from E_4 to E_2. Which of the following transitions could be associated with the absorption of the red light ?



A E_2 to E_3

B E_1 to E_4

C E_3 to E_2

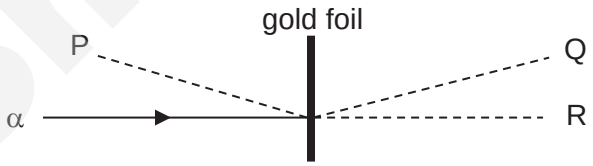
D E_4 to E_1

28 The momentum of a proton is measured with an uncertainty of 1.0%. Given that it has kinetic energy of 1.00 MeV, which of the following is the minimum uncertainty in its position?

A 1.1×10^{-11} m **B** 2.9×10^{-12} m **C** 1.1×10^{-12} m **D** 7.0×10^{-13} m

29 In an experiment on α-particle scattering, α-particles are directed onto a gold foil, and detectors are placed at positions P, Q and R as shown in the diagram below.

What is the distribution of α-particles as recorded at P, Q and R respectively?



	Position P	Position Q	Position R
A	none	none	all
B	none	some	most
C	most	some	fewer than at position Q
D	fewer than at position Q	some	most

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30 Which statement about alpha, beta and gamma radiation is correct?

A Alpha radiation has the greatest ionising power.
B Beta radiation has the greatest ionising power.
C Gamma radiation has the greatest ionising power.
D Alpha, beta and gamma radiation have nearly equal ionising powers.

END OF PAPER

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General Certificate of Education Advanced Level
Higher 2

NAME

CG **INDEX NO.**

PHYSICS 9749/02

Preliminary Examination **11th September 2017**
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

.

For Examiners' Use	
Q1	/ 8
Q2	/ 9
Q3	/ 15
Q4	/ 9
Q5	/ 20
Q6	/ 19
Total marks	/ 80

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For Examiner's Use

DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 In order to determine the value of the gravitational acceleration g, a student throws a ball at a speed of 15 m s^{-1} horizontally from a building.

(a) The student collects the following data for the ball when it reaches the ground.

Quantity	Value	Absolute Uncertainty
Vertical displacement	122.500 m	0.002 m
Horizontal displacement	75.000 m	0.002 m

(i) Show that the time taken to reach the ground is 5.0 s. [1]

(ii) The uncertainty of the time taken is 0.4 s.

Determine the value of g, with its associated uncertainty.

g = …… ± …….. m s^{-2} [3]

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(b) In the absence of air resistance, the variation of the vertical speed v of the ball with time t is shown in Fig. 1.1.

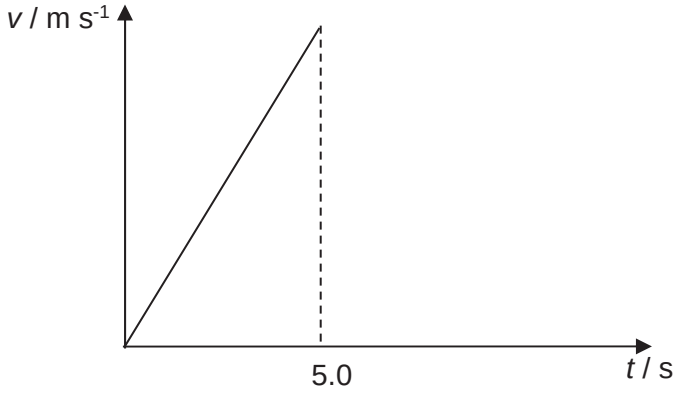

Fig. 1.1

(i) In reality, there is air resistance. Sketch the graph of variation of vertical speed with time on Fig. 1.1, and label this graph Z. [2]

(ii) Explain the shape of the graph Z.

……

……

……

…… [2]

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2 Truck X of mass 22 000 kg and moving at a speed of 3.0 m s^{-1}, catches up and collides with Truck Y moving at 1.0 m s^{-1} moving in the same direction as shown in Fig. 2.1.

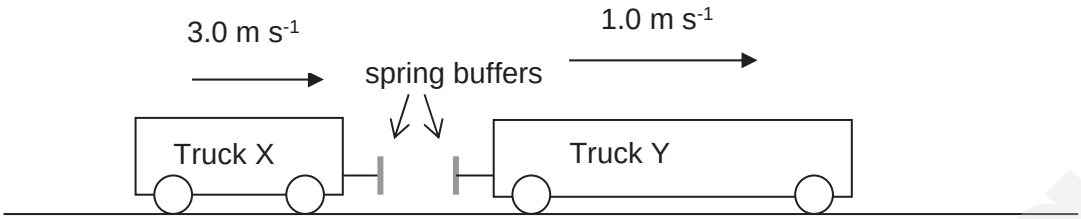

Fig. 2.1

Fig. 2.2 shows how the speeds of the trucks vary with time *t* before, during and after the collision.

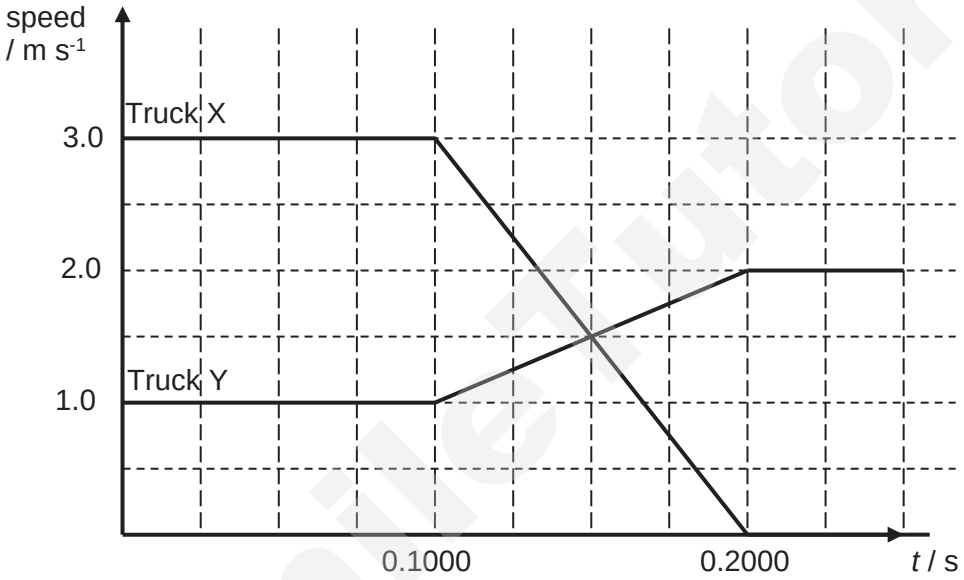

Fig. 2.2

(a) Using Fig. 2.2, show that the mass of Truck Y is 66000 kg. [1]

(b) Showing your working clearly, explain whether this collision is elastic. [2]

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(c) **(i)** State the time at which the trucks are closest to each other.

t = …… s [1]

(ii) **1.** Calculate the total kinetic energy of the two trucks at the time stated in **(i).**

total kinetic energy = …… J [1]

2. Hence, calculate the maximum elastic potential energy stored in the spring buffer during the collision.

maximum elastic potential energy stored = …… J [1]

(d) **(i)** Calculate the magnitude of the impulse exerted by Truck X on Truck Y.

magnitude of impulse = …… N s [2]

(ii) If the duration of the collision is reduced, with the initial and final speeds of both trucks unchanged, state and explain how this affects your answer in **(i)**.

……

……

…… [1]

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3 **(a)** State what is meant by *coherent sources*.

……

……

……

…… [2]

(b) A stereo system in a large hall has two identical speakers, S_1 and S_2, placed 1.2 m apart as shown in Fig. 3.1. The amplitude of the output of each speaker is proportional to the potential difference across its terminals, which is adjusted by means of a balance control.

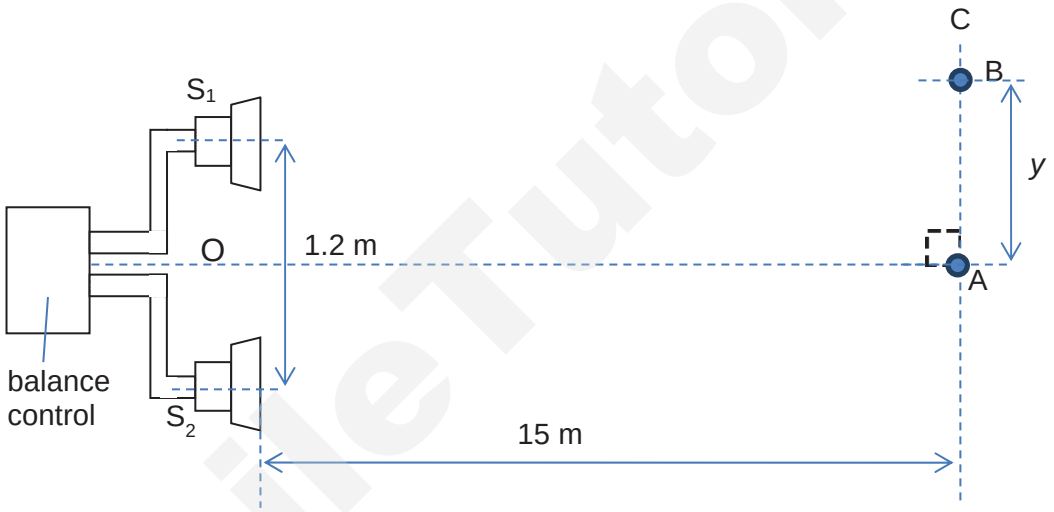

Fig. 3.1 (not to scale)

Initially, the speakers are emitting signals of frequency 1000 Hz which are in phase. The balance control is set such that the potential difference across the terminals of both speakers are the same.

Line AC is 15 m away from the speakers. An observer hears a loud sound of intensity I_{max} at A. As he moves along the line AC, 15 m away from the speakers, he observes that the intensity of the sound first falls to zero at point B, a distance *y* from A. The speed of sound in air is 330 m s^{-1}.

(i) Determine the distance *y*.

y = …… m [2]

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(ii) By calculating the path difference of the two sound waves arriving at B, determine the next higher frequency of the speaker such that point B would also be a point of zero intensity.

frequency = …… Hz [3]

(iii) With the speakers emitting the original signal frequency of 1000 Hz, the balance control is now adjusted such that the potential difference across the terminals of S_1 is reduced while the potential difference across the terminals of S_2 is unchanged.

Suggest and explain any changes to the sound heard at B.

……

……

……

…… [2]

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(c) Monochromatic light is passed through a rectangular slit of width b of 0.20 mm. The light is observed on a screen placed 0.75 m from the slit, as shown in Fig. 3.2.

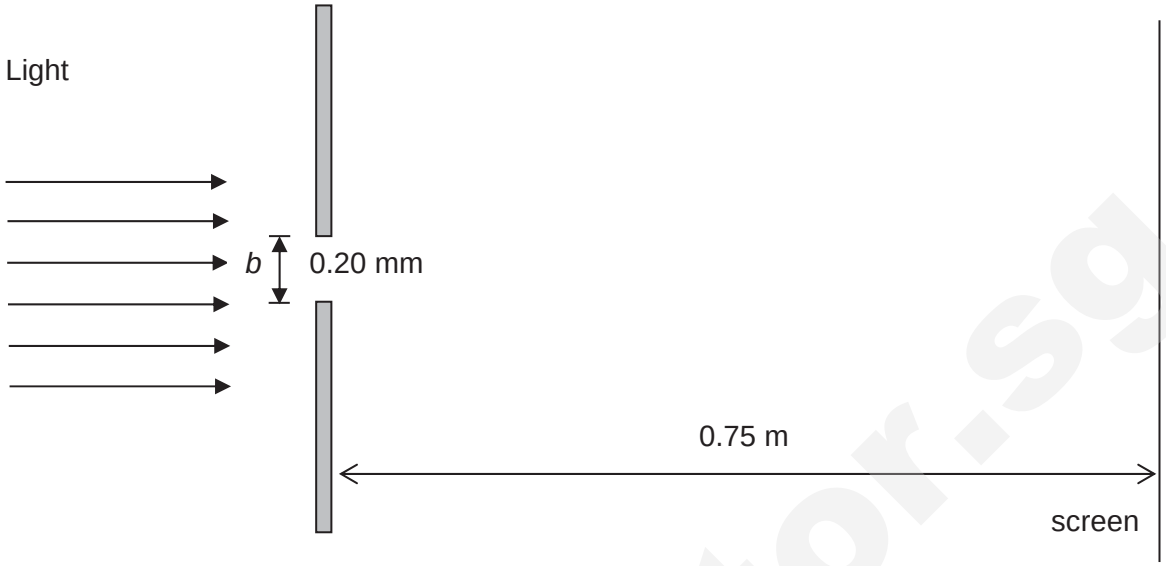

Fig. 3.2

Light passing through the slit is diffracted through an angle θ.

The variation of the intensity I of the light with the angle θ of diffraction is shown in Fig. 3.3. The maximum value of intensity is I_0.

The angular separations between successive minima are the same.

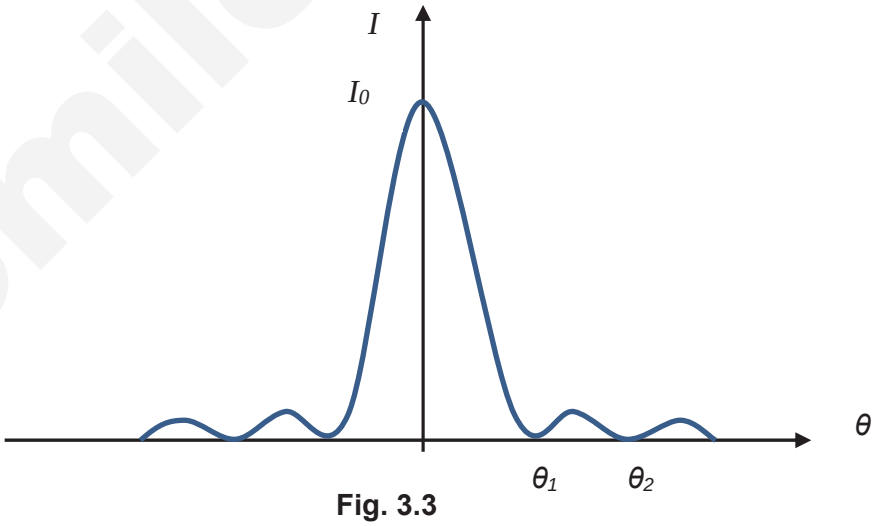

Fig. 3.3

(i) The value of θ_2, the location of the second order minima, is 0.338°. Determine the wavelength of the monochromatic light.

wavelength = …….. nm [2]

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(ii) Determine the angle between two beams of light incident on the slit, each of the same wavelength as in **(i)**, such that their diffraction patterns are just resolved. Explain your working.

angle = ……° [2]

(iii) Sketch, on the axes of Fig. 3.3, how the intensity of the light varies with θ if the slit width is halved. Label any relevant intercepts on your sketch. [2]

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4 **(a)** Define the *tesla*.

……

……

……

…… [3]

(b) Ions, all of the same element, are travelling in a vacuum with a speed of 9.6×10^4 m s^{-1}. The ions are incident normally on a uniform magnetic field B of flux density 320 mT. The ions follow semicircular paths A and B before reaching a sensor, as shown in Fig. 4.1.

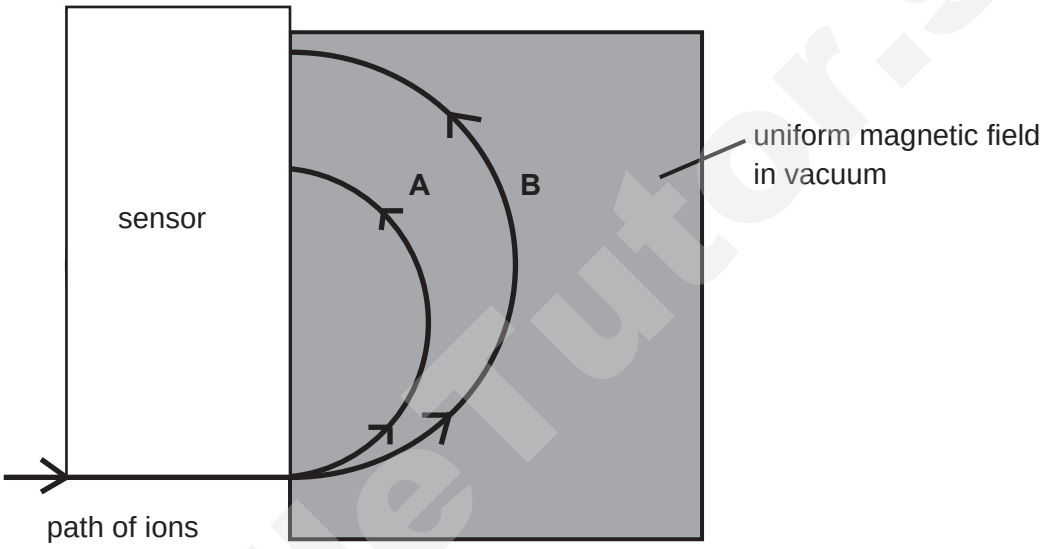

Fig. 4.1

The diameters of paths A and B are 6.2 cm and 12.4 cm respectively. The ions in path B each have charge $+1.6 \times 10^{-19}$ C.

(i) Explain why the path of the ions in the magnetic field is an arc of a circle.

……

……

……

……

……

……

……

…… [3]

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(ii) Calculate the mass of the ions in path B.

mass = ……kg [2]

(iii) Explain the reason for the difference in radii of the paths A and B of the ions.

……

……

……

…… [1]

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5 **(a)** **(i)** Define *binding energy*.

……

……

…… [1]

(ii) Sketch a graph in Fig. 5.1 to show the variation of the binding energy per nucleon with nucleon number. Label the value of nucleon number and binding energy per nucleon for the isotope that has the highest binding energy per nucleon. [2]

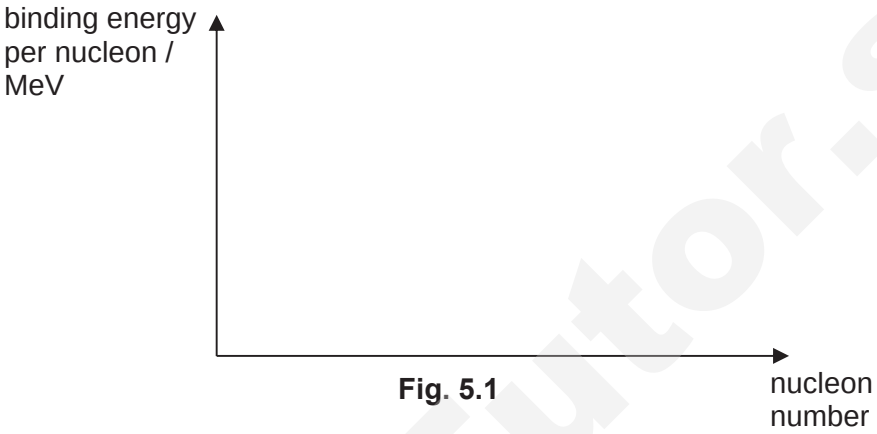

Fig. 5.1

(iii) With reference to your graph drawn in Fig. 5.1, explain how fission can be a potential source of energy.

……

……

……

…… [2]

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(iv) A typical nuclear fission reaction that involves uranium-235 is represented by the equation

$$^{235}_{92}U + n \rightarrow Kr + {}^{141}_{56}Ba + 3n$$

Data for the binding energy per nucleon for the different nuclei are given in the table below:

Nuclei	Binding energy per nucleon / MeV
$^{235}_{92}U$	7.59
Kr	8.51
$^{141}_{56}Ba$	8.33

1. Deduce the number of protons and neutrons in the Kr nucleus.

number of protons = ……

number of neutrons = ……[2]

2. Calculate the energy released in the above reaction.

energy released = …… J [2]

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(b) A stationary $^{228}_{88}\mathrm{Ra}$ nucleus undergoes beta minus decay to form an actinium isotope. The actinium isotope and beta particle move as shown in Fig. 5.2.

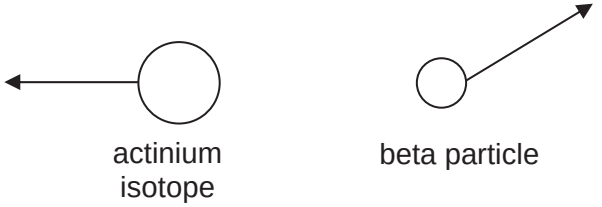

Fig. 5.2

Explain why a neutrino must also be released in this process.

……

……

……[2]

(c) Scientists have worked out the age of the Moon by dating rocks brought back by the Apollo missions. They use the decay of potassium $^{40}_{19}\mathrm{K}$ to argon $^{40}_{18}\mathrm{Ar}$, which is stable. The decay constant of potassium-40 is 5.3×10^{-10} per year.

(i) Explain what is meant by the decay constant of potassium-40 being 5.3×10^{-10} per year.

……

……

……[1]

(ii) Sketch a labelled graph on Fig. 5.3 to show how the activity of $^{40}_{19}\mathrm{K}$ changes with time if the initial activity is A_o. Mark on your graph the value of the half-life of $^{40}_{19}\mathrm{K}$. [2]

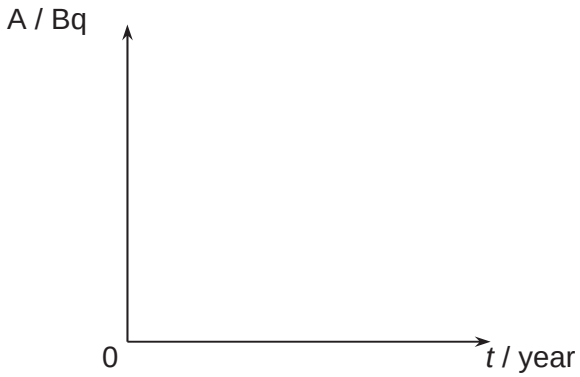

Fig. 5.3

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(iii) In one rock sample the scientists found 0.84 μg of argon-40 and 0.10 μg of potassium-40.

1. Calculate the activity of the potassium-40 in the rock sample.

activity = …… Bq [2]

2. Calculate the age of the rock sample in years.

age of rock sample = …… years [2]

3. State any assumption that you have made for the calculation in **2**.

……

……[1]

(iv) Explain why the determination of the decay constant by measuring the mass and activity of a sample is not suitable for nuclides that have relatively large decay constants.

……

……

……[1]

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6 A capacitor is an electrical device which can store charges and energy. A simple parallel plate capacitor consists of two parallel conducting plates separated by an insulator, as shown in Fig. 6.1.

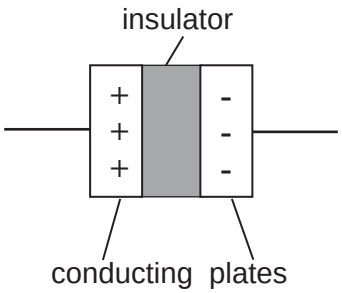

Fig. 6.1

When charged, the two plates carry opposite charges of the same magnitude. The relationship between the amount of charge stored Q, the potential difference V between the plates and the capacitance C is given by the equation

$$Q = CV$$

(a) Deduce the base units of C.

base units = ... [3]

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(b) The capacitor is now charged. Fig. 6.2 shows the values of potential difference *V* and the corresponding amount of charge *Q*.

***V*/ V**	***Q*/ μC**
0.0	0.0
0.4	1.9
1.3	6.1
3.0	14.3
3.3	15.5
4.2	19.7
5.1	23.5

Fig. 6.2

On Fig. 6.3,

(i) plot the missing data points from Fig. 6.2. [2]

(ii) sketch the best fit line to show the variation of the amount of charge *Q* with the potential difference *V* between the plates. [1]

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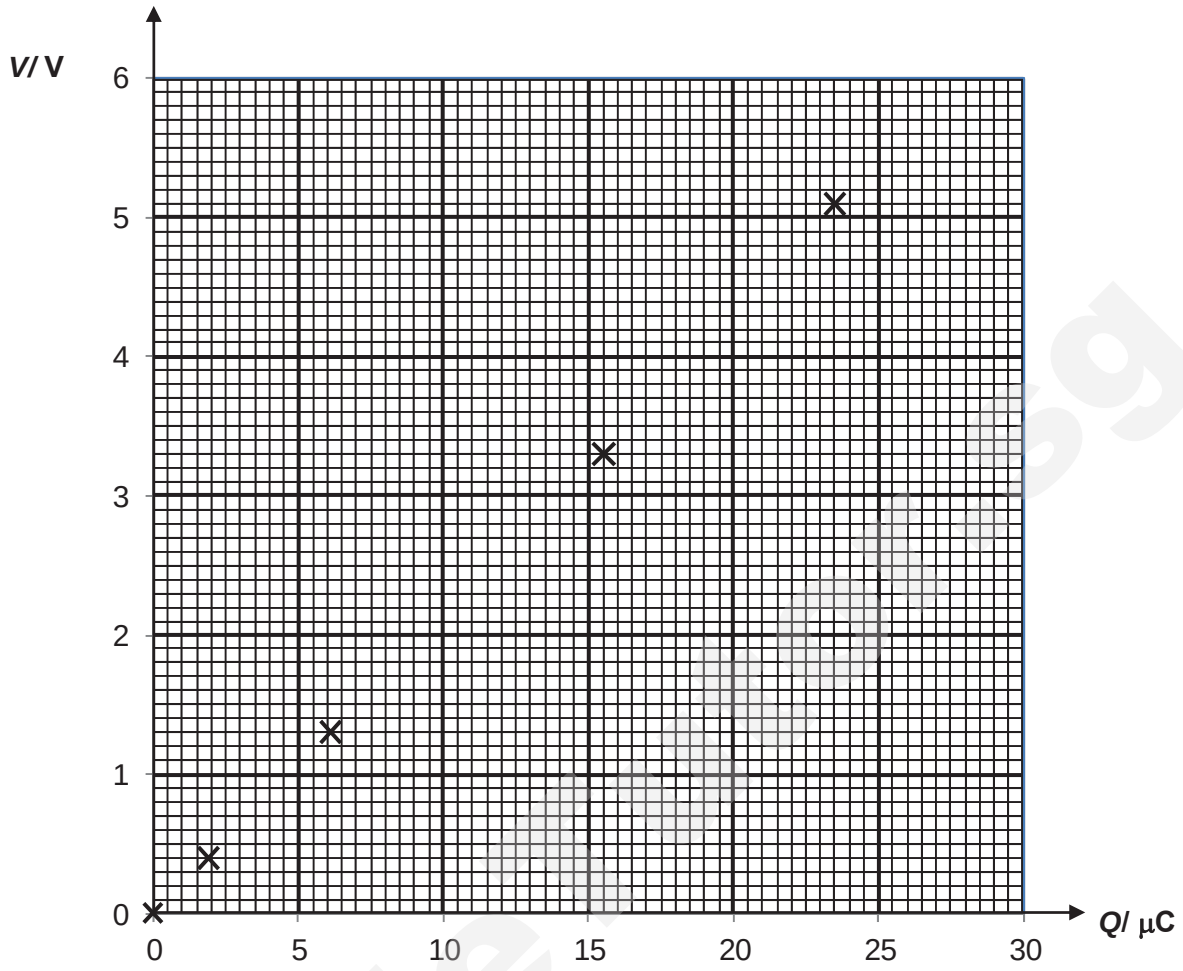

Fig. 6.3

(iii) State the quantity represented by the:

1. gradient of the graph,

..... [1]

2. area under the graph.

..... [1]

(iv) Hence, show that the energy E stored in a capacitor is $\frac{1}{2} CV^2$.

[1]

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(c) The capacitor is now discharged by connecting it across a resistor of resistance R as shown in Fig. 6.4.

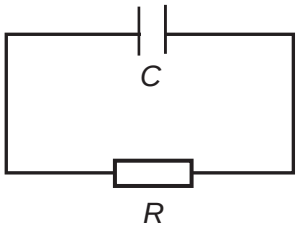

Fig. 6.4

Fig. 6.5 shows the variation with time t of the potential difference V across the resistor.

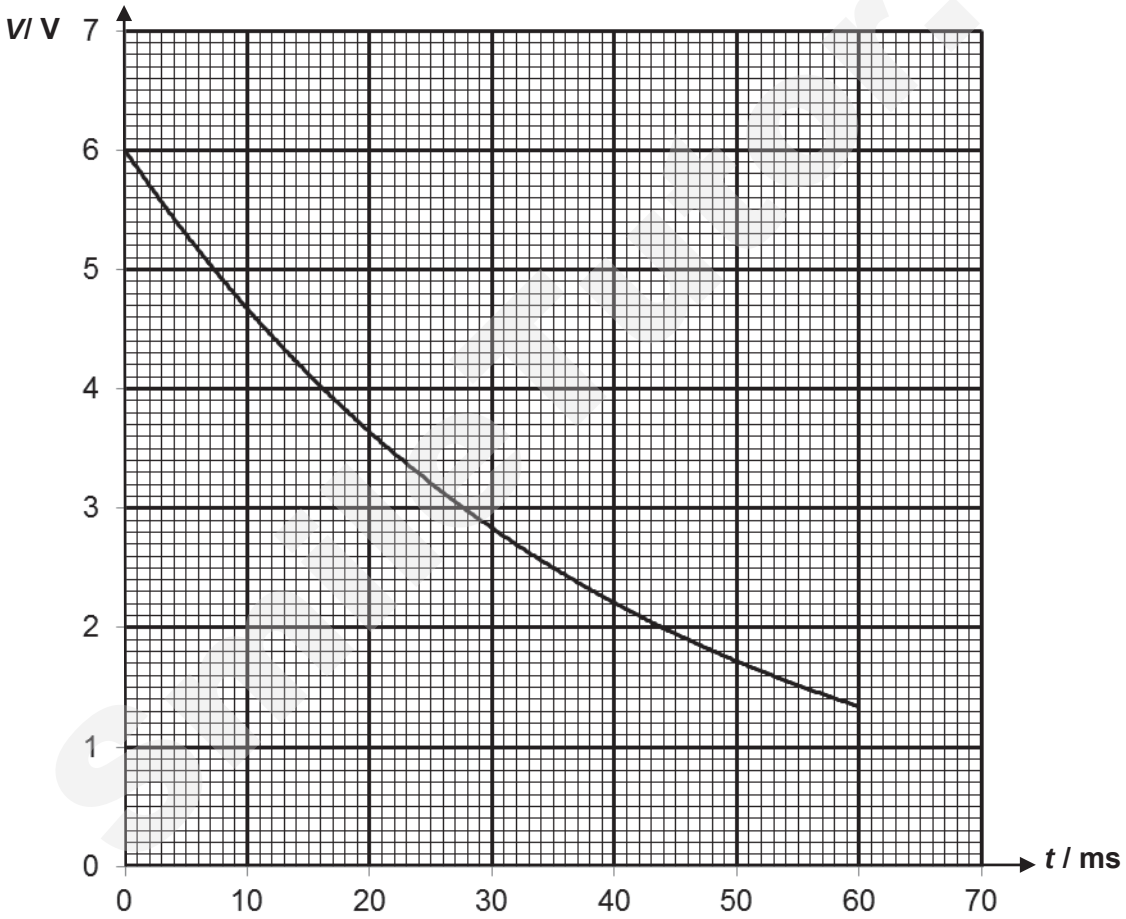

Fig. 6.5

(i) Using Fig. 6.3 and Fig. 6.5, determine the initial amount of charge stored.

charge = ... μC [2]

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(ii) Hence, calculate the capacitance *C*.

capacitance = ... C V^{-1} [2]

(iii) Calculate the energy lost when the capacitor has been discharged for 45 ms.

energy lost = ... J [3]

(d) The graph in Fig. 6.5 can be represented by the following equation, where V_o is the initial potential across the resistor *R*.

$$V = V_o e^{-t/RC}$$

State how the value of *RC* affects the rate of discharge of the capacitor.

..... [1]

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(e) Fig 6.6 shows an A.C. supply connected to resistor-capacitor (RC) circuit containing an ideal diode. Fig 6.7 shows the potential difference measured by the CRO.

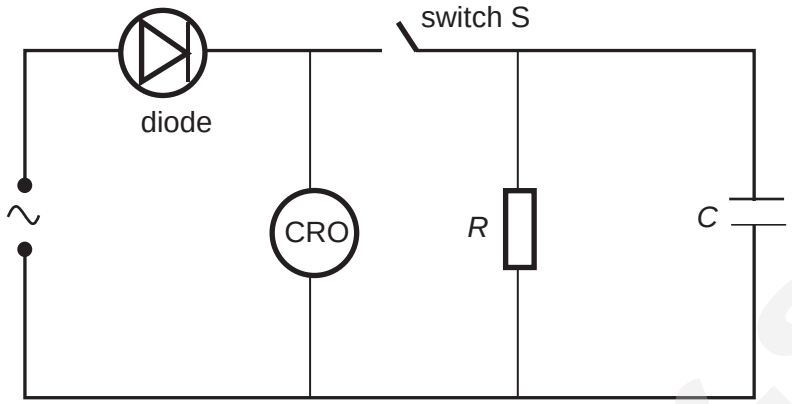

Fig. 6.6

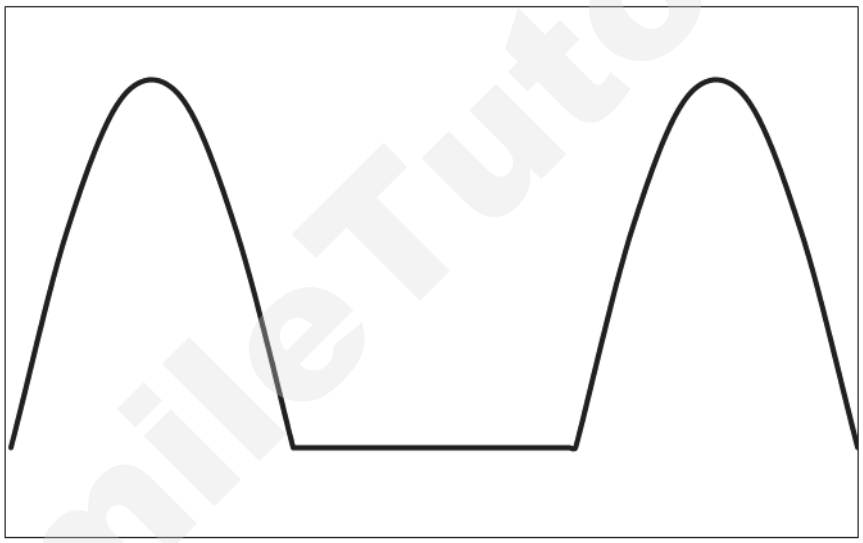

Fig. 6.7

Switch S is now closed. When the diode is in forward bias, current flows through both the resistor and the capacitor. When the diode is in reverse bias, the capacitor discharges through the resistor.

(i) Sketch on Fig. 6.7, the expected display on the CRO. [1]

(ii) State what the RC circuit does to the wave on the CRO.

.....[1]

END OF PAPER

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General Certificate of Education Advanced Level
Higher 2

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PHYSICS 9749/03

Preliminary Examination **15th September 2017**
Paper 3 Longer Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions in Section A, and **one** of the two questions in Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

.

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Q1	/ 7
Q2	/ 13
Q3	/ 20
Q4	/ 20
Q5	/ 20
Q6	/ 20
Total marks	/ 80

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DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A: Answer all questions.

1 A uniform rod of weight 20 N is freely hinged to a wall at P as shown in Fig. 1.1. It is held horizontal by an elastic cord made of material X of force constant 10 N cm^{-1}, attached at Q at an angle of 15° to the rod.

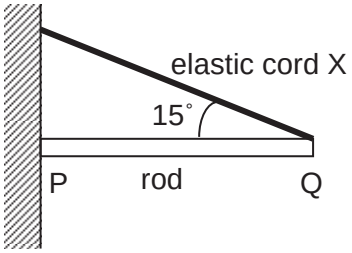

Fig. 1.1

(a) Show that the extension of the elastic cord X is 3.86 cm. [2]

(b) Determine the magnitude of the resultant force acting at P.

magnitude of resultant force at P = …… N [3]

(c) The elastic cord X is now replaced by two other identical elastic cords of the same unstretched length as elastic cord X. These two elastic cords are connected in parallel. The rod PQ remains horizontal.
State and explain the value of the force constant of each of the new elastic cords.

……

……

……[2]

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2 (a) State the *first law of thermodynamics*, indicating the directions of all energy changes.

.....

.....

..... [2]

(b) A heat pump contains a fixed mass of ideal gas undergoing a cycle of changes of pressure, volume and temperature as illustrated in Fig. 2.1.

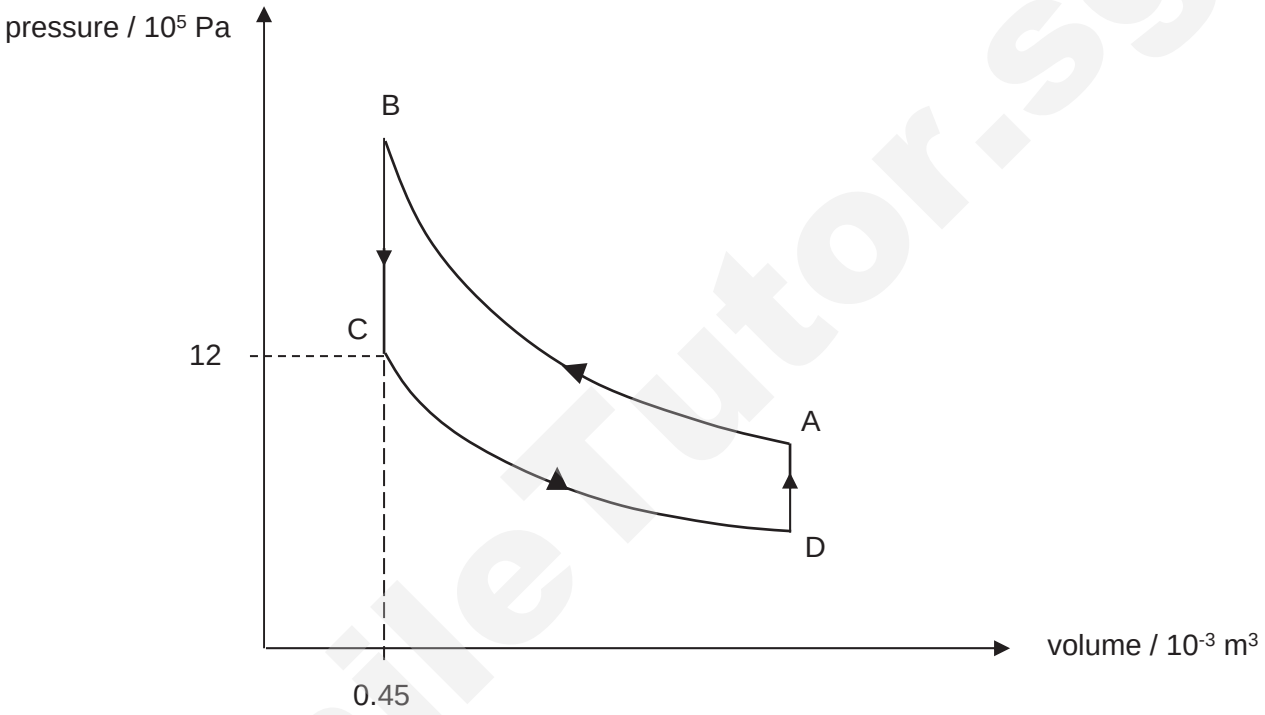

Fig. 2.1

The increase in internal energy which takes place during three of the changes are as shown in Fig. 2.2. It is also known that no heat is supplied in the changes A → B and C → D.

(i) Complete Fig. 2.2.

Change	Increase in internal energy / J	Heat supplied to gas / J	Work done on gas / J
A → B	720		
B → C	-810		
C → D	- 360		
D → A			

Fig 2.2 [4]

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(ii) Given that the temperature at C is 360 K, calculate the number of molecules, N, in the heat pump.

number of molecules = ……[2]

(iii) Given that the total kinetic energy of the gas molecules, E_K is given as E_K = 3/2 NkT, using your answers in **(i)** and **(ii)**, determine the temperature at D.

temperature = …… K [3]

(iv) Given that the gas is Helium-4, calculate the root-mean-square speed of the Helium molecules at C.

r.m.s speed = …… m s^{-1} [2]

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3 (a) A satellite is in a geostationary circular orbit of radius *r* about the Earth of mass *M*, and appears to remain above the same point on the Earth. The mass of the Earth may be assumed to be concentrated at its centre.

(i) State two features of a geostationary satellite of the Earth.

1. ……

……

2. ……

……[2]

(ii) Show that the period *T* of the orbit of the satellite is given by the expression

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where G is the gravitational constant. Explain your working.

[3]

(iii) The mass *M* of the Earth is 6.0×10^{24} kg.

Determine the radius of the geostationary orbit.

radius = …….. m [2]

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(b) The variation of the resultant gravitational potential due to the Earth and the Moon along a line XY joining the centres of the Earth and Moon is as shown in Fig. 3.1.

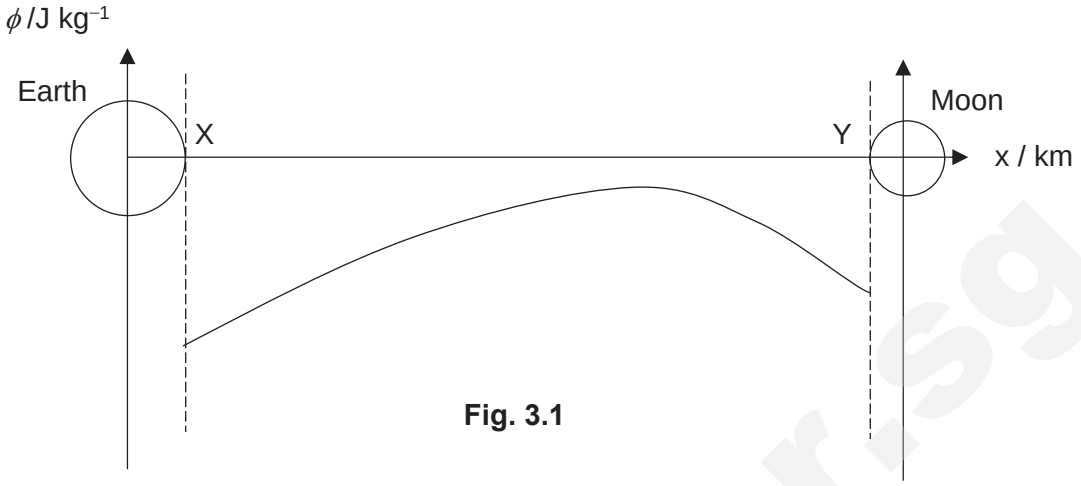

Fig. 3.1

(i) Given that the mass of the Moon is 7.3 x 10^{22} kg and the distance between the centres of the Earth and Moon is 380 000 km, show that the distance from the centre of the Earth along XY, where the net gravitational field strength is zero, is 342 000 km.

[1]

(ii) Hence, sketch the corresponding net gravitational field strength due to the Earth and the Moon in Fig. 3.2. [2]

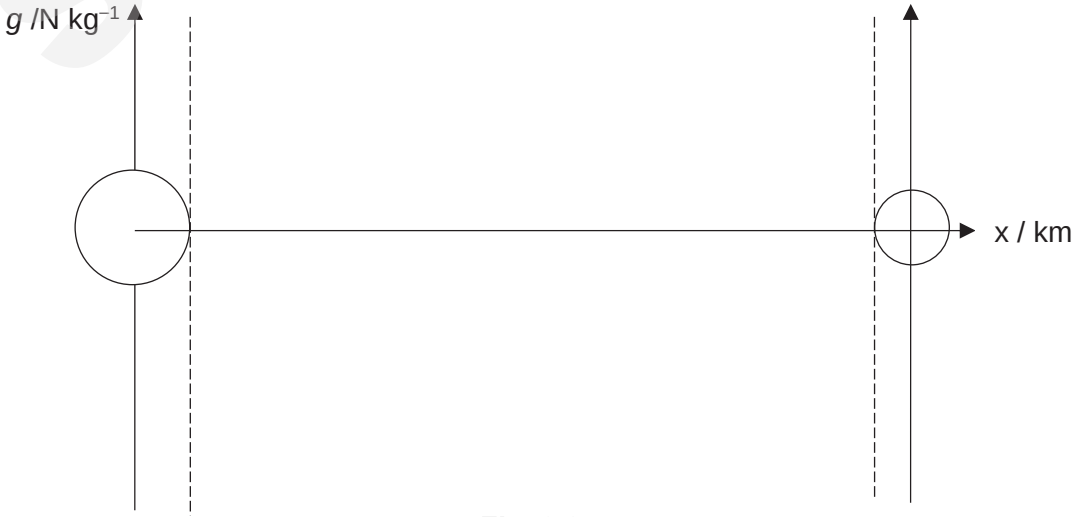

Fig. 3.2

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(c) Two point charges A and B are separated by a distance of 8.0 cm in a vacuum, as illustrated in Fig. 3.3.

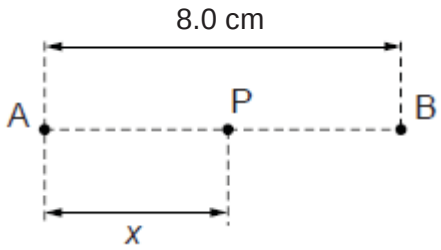

Fig. 3.3

Point P is at a distance *x* from A along AB. The variation of the resultant potential due to charges A and B is as shown in Fig. 3.4.

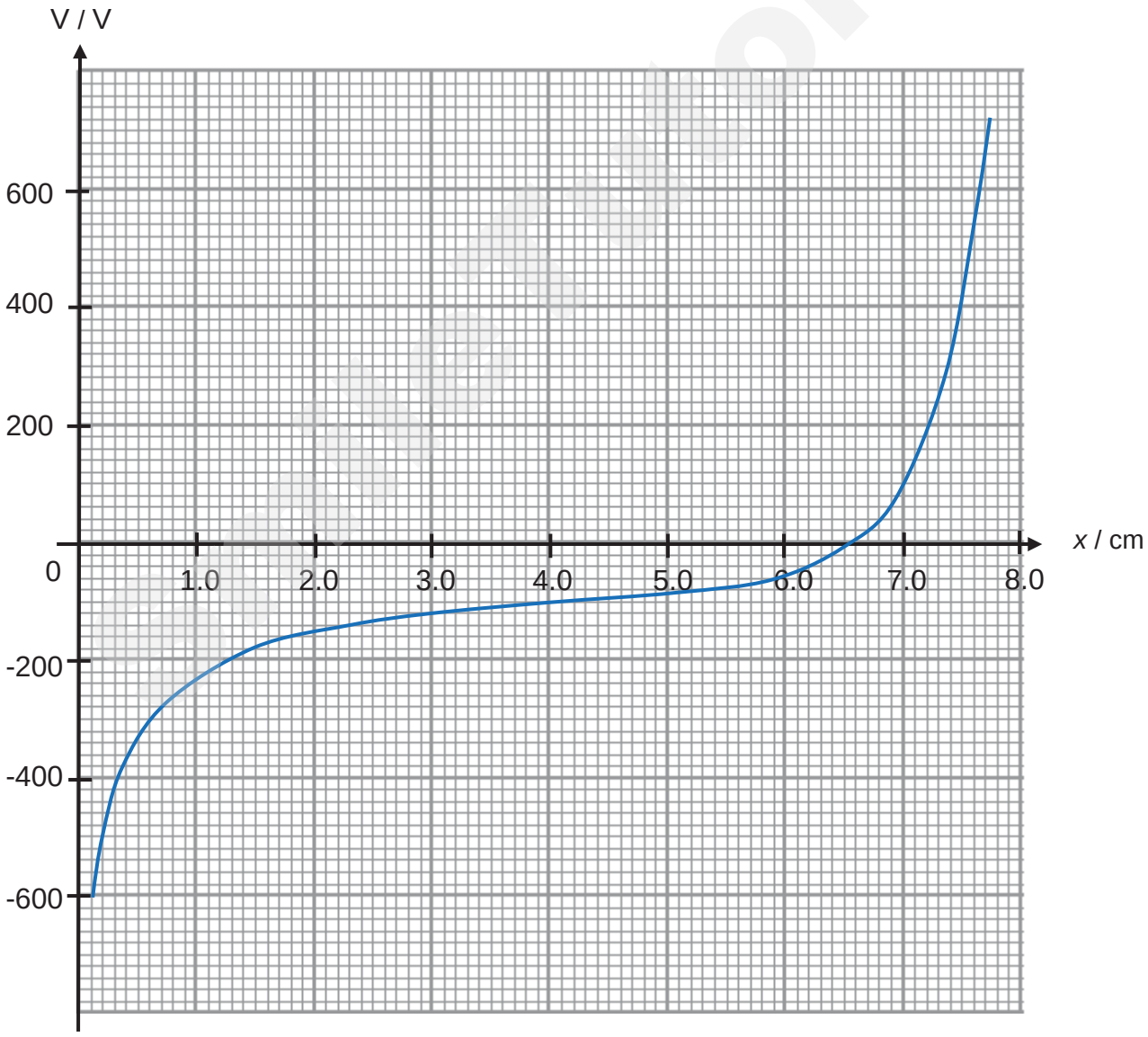

Fig. 3.4

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(i) State and explain whether the two charges are of the same sign.

……

……

……[2]

(ii) Calculate the ratio of the numerical value of $\frac{\textit{Charge of A}}{\textit{Charge of B}}$.

ratio = ……[2]

(iii) State and explain the direction of the electric field at the point P, where x = 2.0 cm.

……

……

……

……[2]

(iv) Sketch the variation of the electric field strength with x in Fig. 3.5. Label where appropriate.

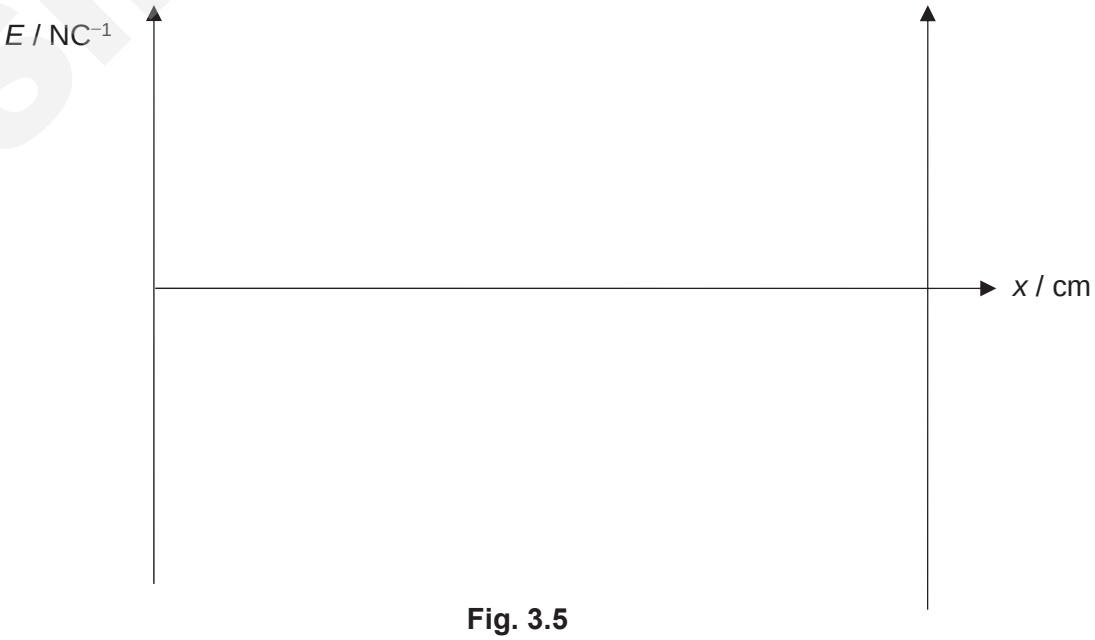

Fig. 3.5

[1]

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(v) When a -2.0 nC charge is moved from x = 3.0 cm to 6.0 cm, calculate the change in kinetic energy of the -2.0 nC charge.

change in kinetic energy = …… J [2]

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4 (a) By reference to the photoelectric effect, explain

(i) what is meant by *work function*,

……

……[1]

(ii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energies up to a maximum value.

……

……

……

……

……

……[2]

(iii) In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface, and the maximum kinetic energy E_{max} of $1/\lambda$ as shown in Fig. 4.1.

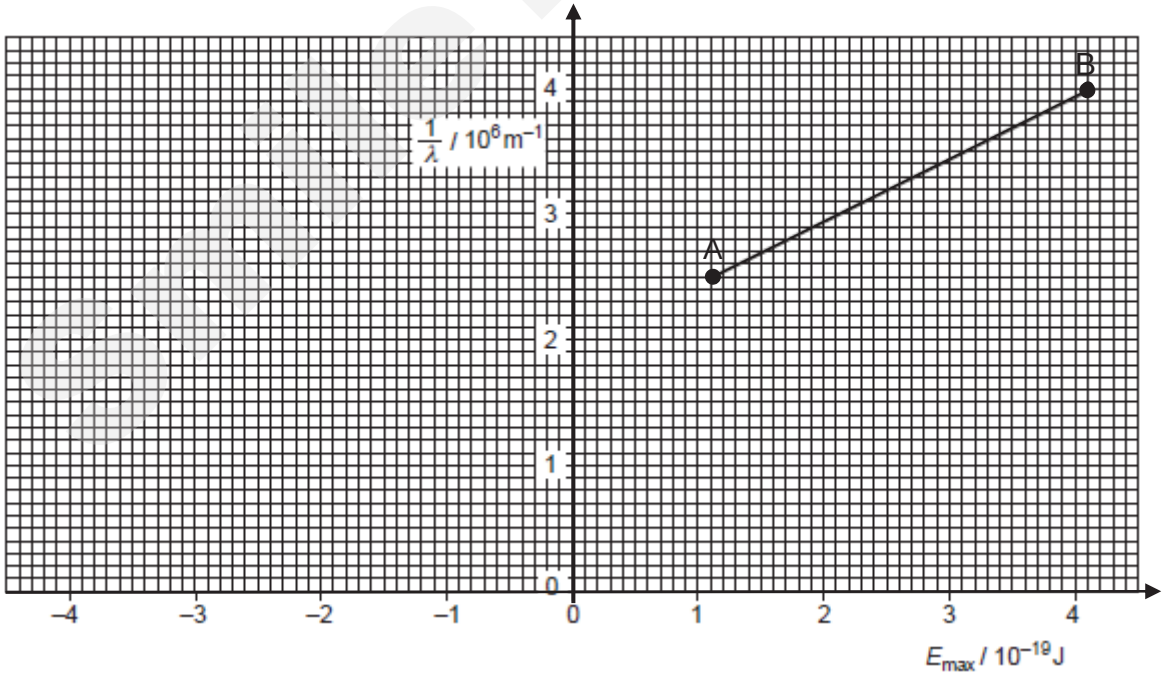

Fig. 4.1

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1. Without using the value of the Planck constant, determine the work function of the metal surface.

work function = …… J [2]

2. Using points A and B, determine the Planck constant.

Planck constant = …….. J s [3]

(b) Fig. 4.2 shows how x-rays are produced inside an x-ray tube. The electrons emitted at the filament are accelerated from rest using an accelerating voltage to hit a target of heavy metal at the anode and produce x-rays as a result.

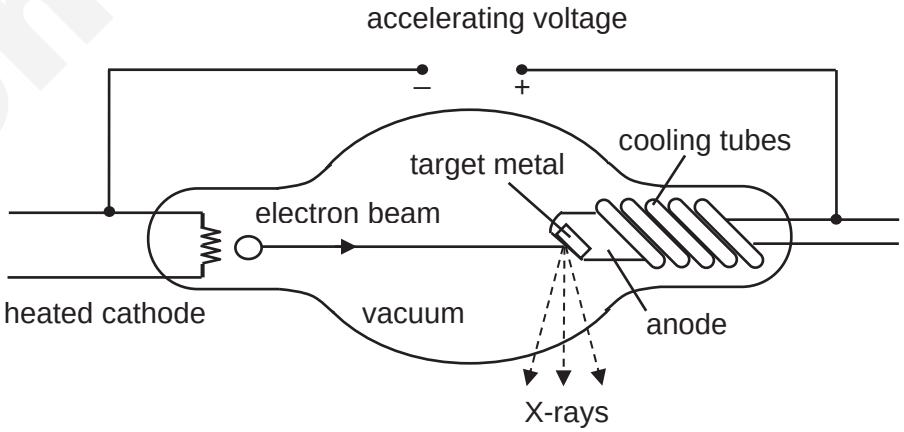

Fig 4.2

A graph of relative intensity against wavelength of the emitted radiation is as shown in Fig. 4.3.

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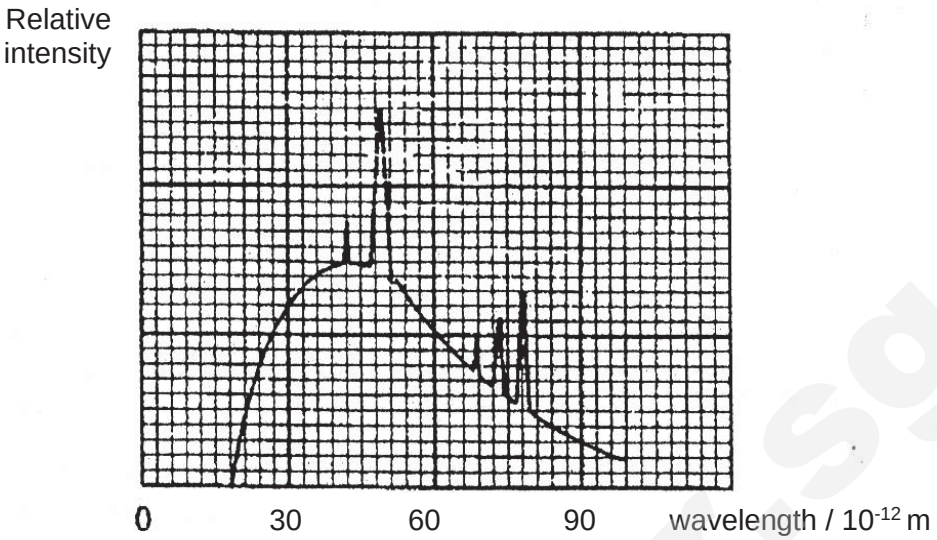

Fig. 4.3

(i) State and explain what must be done to the accelerating voltage if the minimum wavelength of the x-rays emitted is to be doubled.

……

……

……

……

……

……

……[2]

(ii) Determine the accelerating voltage used to produce the minimum wavelength as shown in Fig. 4.3.

accelerating voltage = …….. kV [2]

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(c) Electrons, accelerated through a potential difference, are incident on a very thin carbon film, with speed v as shown in Fig. 4.4.

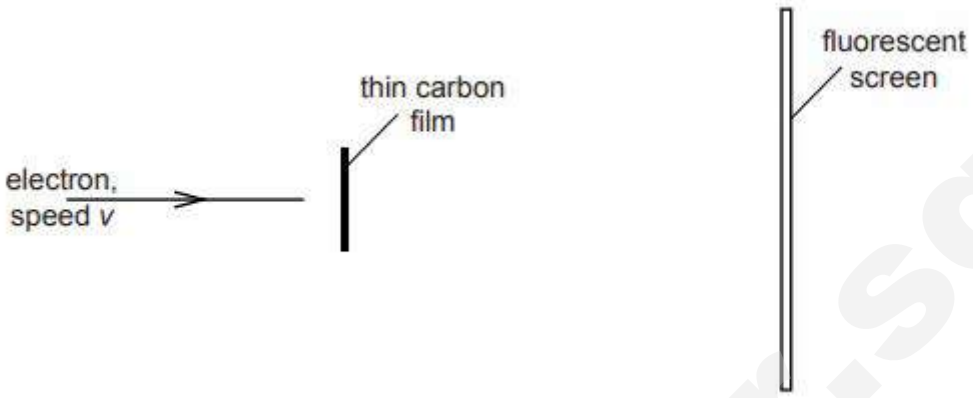

Fig. 4.4

The emergent electrons are incident on a fluorescent screen. A series of concentric rings is observed on the screen.

(i) State and explain what the observed rings suggest about the nature of the electrons.

……

……

……

……

……

……[2]

(ii) The stream of electrons is now replaced by a stream of alpha particles arriving at the thin film with the same speed v. State and explain the effect, if any, on the rings observed on the screen.

……

……

……

……

……

……[3]

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(iii) A proton and an alpha particle are each accelerated from rest through the same potential difference. Determine the ratio

$$\frac{\text{de Broglie wavelength of the proton}}{\text{de Broglie wavelength of alpha particle}}$$

ratio = …… [3]

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For Examiner's Use

Section B: Answer ONE out of TWO questions.

5 (a) The headlights of a car are switched on. The distance along the copper connecting wires between the car battery and one of the headlights is 1.5 m.

(i) The current in the wire is 3.0 A, the cross-sectional area of the wire is 3.0×10^{-7} m^2, and the number density of electrons in copper is 8.5×10^{28} m^{-3}.
Determine the average time that an individual electron will take to drift from the battery to the headlight.

time taken = ... s [2]

(ii) Using your answer in **(i)**, comment on how the light of the headlamp comes on almost immediately when switched on.

.....

.....

..... [1]

(b) An electric heater consists of three similar heating elements A, B, C, connected as shown in Fig. 5.1.

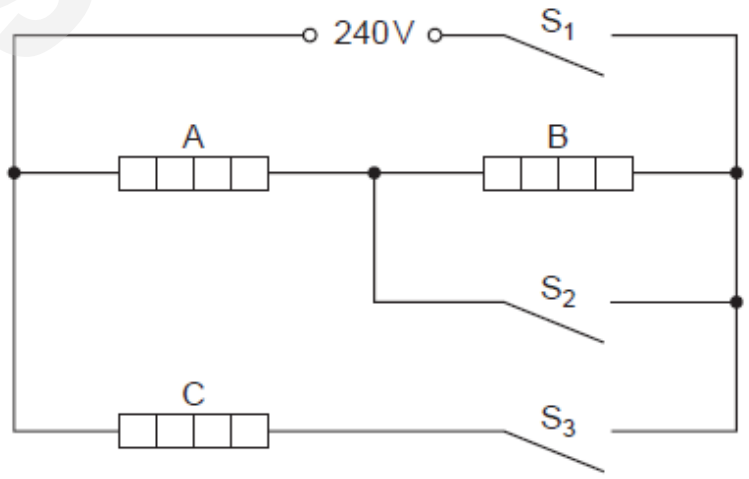

Fig. 5.1

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Each heating element is rated as 1.5kW, 240V and may be assumed to have constant resistance.
The circuit is connected to a 240 V supply.

(i) Calculate the resistance of one heating element.

resistance = ……..Ω [2]

(ii) The switches S_1, S_2 and S_3 may be either open or closed.

1. When S1, S2 and S3 are all closed, state the total power dissipation of the heater.

total power dissipation = …….. kW [1]

2. When S1 is closed, S2 is open, and S3 is open, determine the total power dissipation of the heater.

total power dissipation = …….. kW [2]

3. Hence, determine the total power dissipation of the heater when S1 is closed, S2 is open, and S3 is closed.

total power dissipation = …….. kW [2]

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(c) A circuit used to measure the power transfer from a battery is shown in Fig. 5.2. The battery has an electromotive force (e.m.f.) E and an internal resistance r. The power is transferred to a variable resistor of resistance R, when the potential difference (p.d.) across it is V, and the current through it is I.

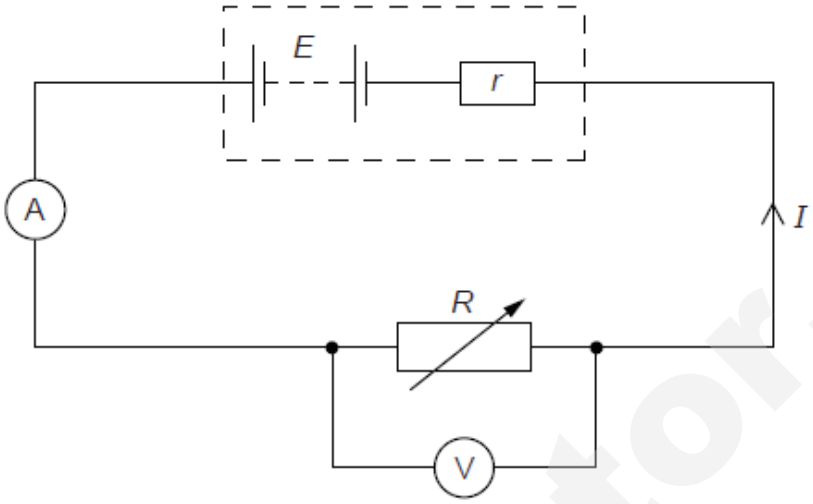

Fig. 5.2

(i) By reference to the circuit shown in Fig. 5.2, distinguish between the definitions of e.m.f. and p.d.

……

……

……

…… [2]

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(ii) The variation with current I of the p.d. V across R is shown in Fig. 5.3.

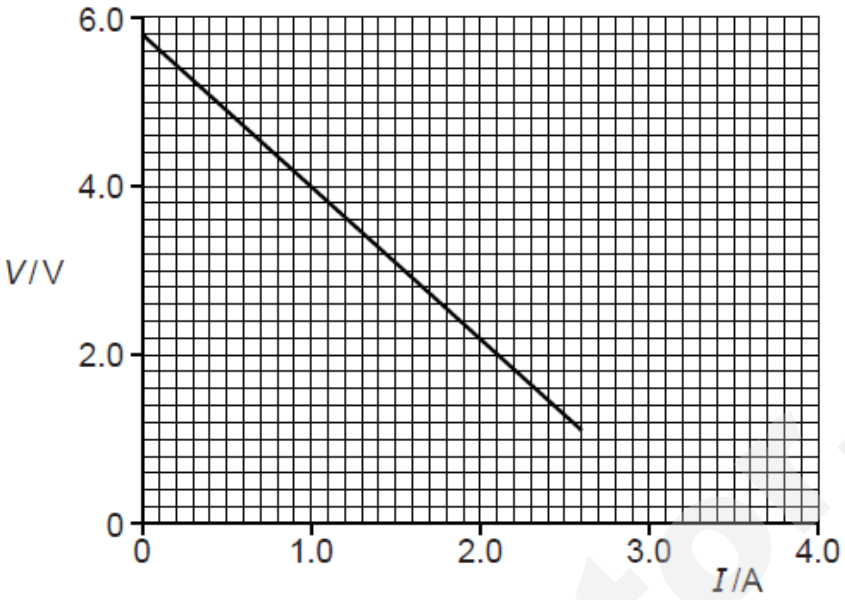

Fig. 5.3

Use Fig. 5.3 to determine

1. the e.m.f. E,

E = ……V [1]

2. the internal resistance r.

r = ……Ω [2]

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(iii) **1.** Using data from Fig. 5.3, show that the power transferred to *R* for a current of 1.6 A is 4.64 W. [1]

2. Use your answers from **(ii)1** and **(iii)1** to calculate the efficiency of the battery for a current of 1.6 A.

efficiency = ……..% [2]

(iv) The variable resistor *R* in Fig. 5.2 is replaced by a few identical lamps connected in parallel. A student claims that as the number of lamps connected in parallel is increased, the lamps become dimmer.
Comment on the student's claim.

……

……

…… [2]

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6 **(a)** A composite block of mass 10 kg, made of woods of different densities ρ_1 and ρ_2, floats in still water of density ρ_w, as shown in Fig. 6.1. Each portion of wood is of height x and of a base with cross-sectional area A.

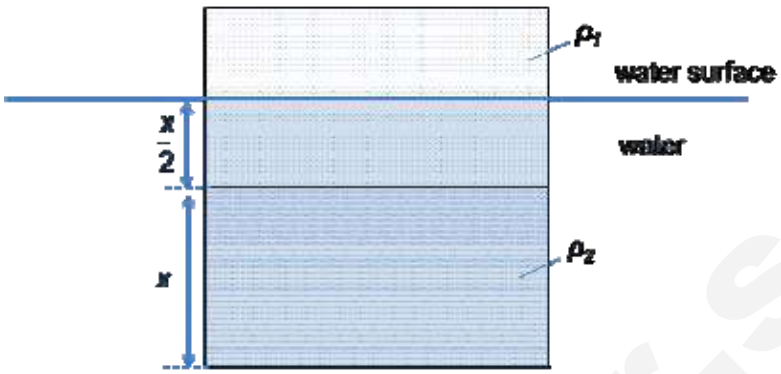

Fig. 6.1

(i) The block is pushed down by a distance l into the water without totally submerging it, and is then released.
It can be shown that the acceleration a of the block is given by

$$a = -\frac{\rho_w g}{(\rho_1 + \rho_2)x} l$$

Explain why the expression leads to the conclusion that the block bobs up and down in simple harmonic motion.

……

……

……

……[2]

(ii) The depth h of the block is measured from below the water surface to the base of the block as shown in Fig. 6.2.

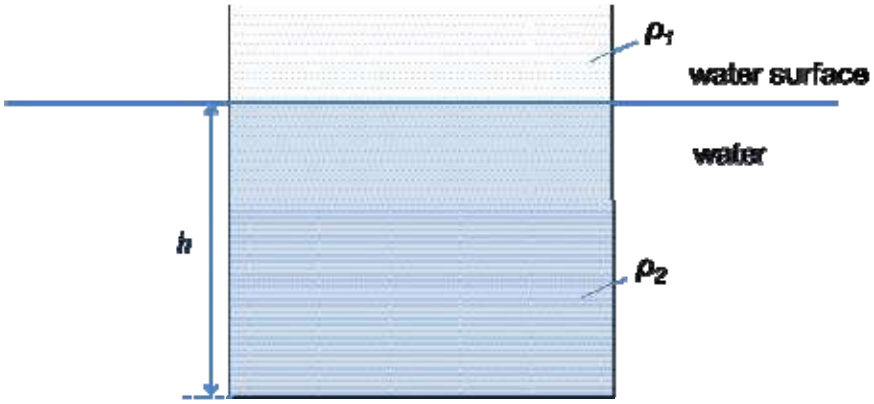

Fig. 6.2

Fig. 6.3 shows the variation with time t of the depth h of the base of the block below the surface.

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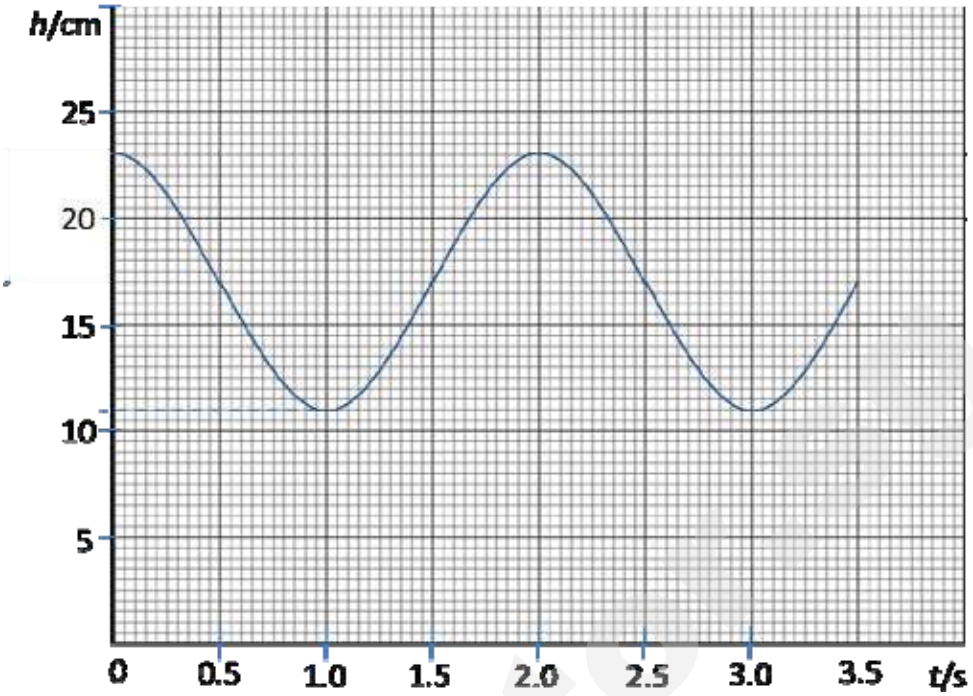

Fig. 6.3

1. Determine the amplitude of the oscillation of the block.

amplitude = …… m [1]

2. Determine the angular frequency of the oscillation.

angular frequency = …… rad s^{-1} [2]

3. Hence, show that the energy of the oscillation is 0.177J. [1]

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(b) **(i)** State Faraday's law of electromagnetic induction.

……

……

……[2]

(ii) A coil with 800 turns is placed in a uniform horizontal magnetic field of flux density 5.0 x 10^{-2} T. The area of the coil perpendicular to the field is 2.5 x 10^{-2} m^2, as shown in Fig. 6.4.

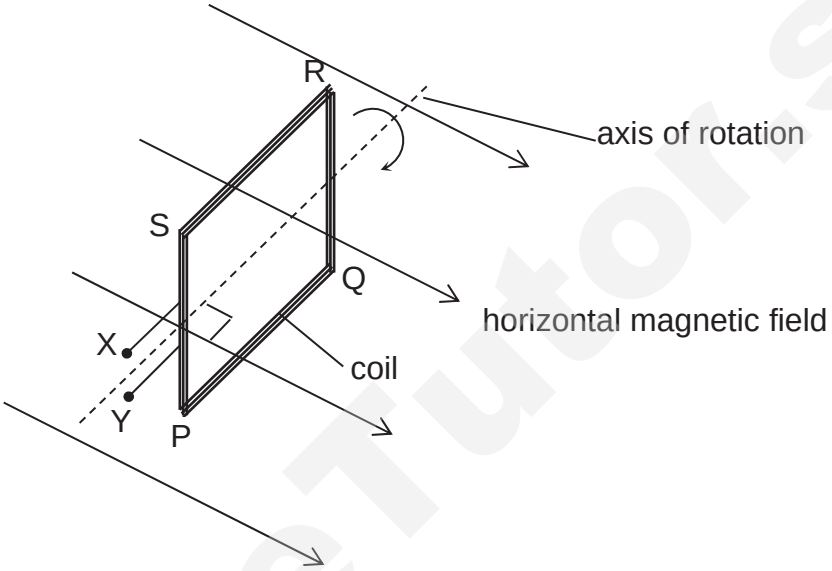

Fig. 6.4

1. Explain why an e.m.f. is induced in the coil.

……

……

……[2]

2. Determine the magnetic flux linkage of the coil.

magnetic flux linkage = …… Wb-turns [2]

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(c) The coil in **(b)** is rotated around the axis shown in Fig. 6.4. The flux linkage Φ of the coil varies with time t as shown in Fig. 6.5.

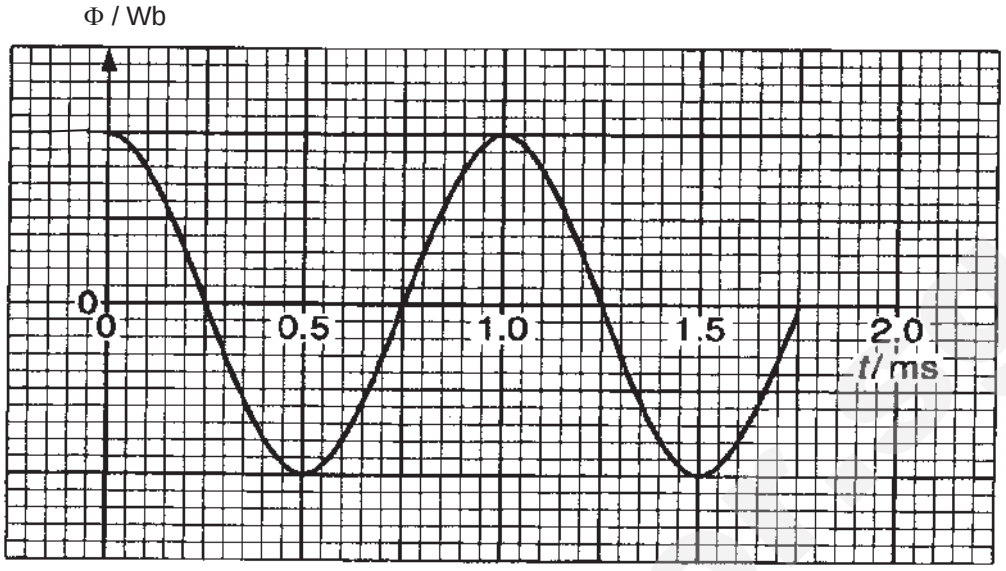

Fig. 6.5

(i) Derive the equation for the induced e.m.f. E of the coil, where N is the number of turns in the coil, B is the magnetic flux density, A is the area of coil, and ω is the angular frequency of the change in magnetic flux linkage.

[2]

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(ii) Sketch on Fig. 6.6 the variation with time of the e.m.f. across XY. Label the maximum value of the e.m.f. [2]

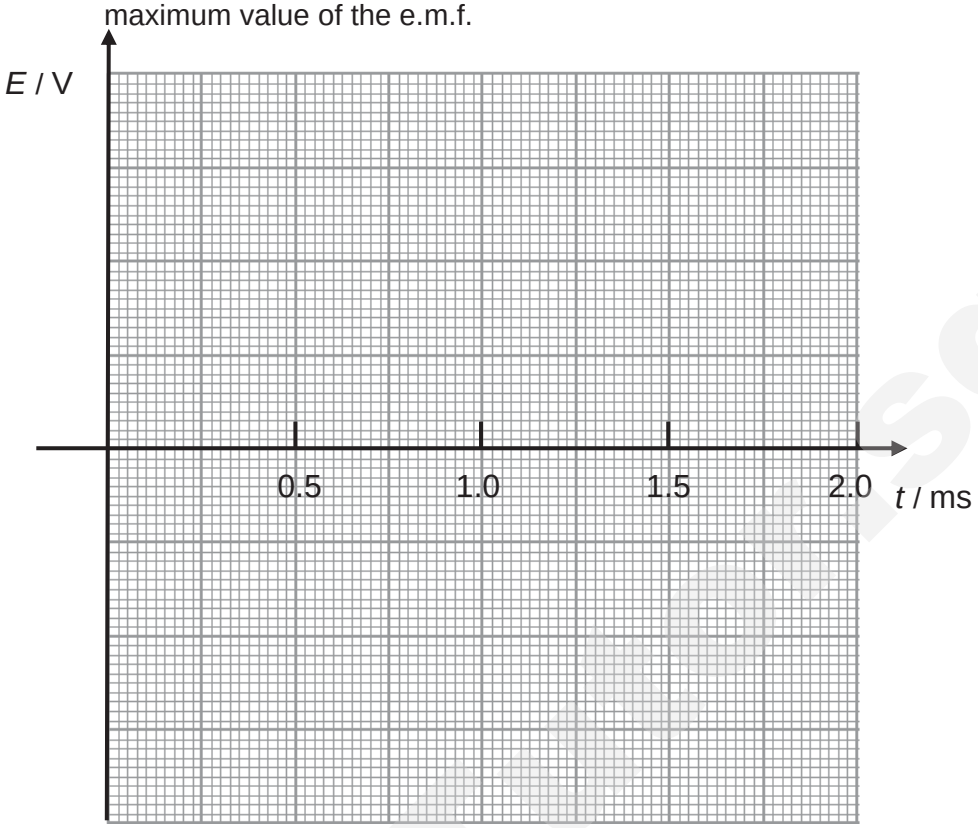

Fig. 6.6

(d) A resistor of resistance 5000 Ω is now connected across XY.

(i) Determine the mean power dissipated in the resistor.

mean power = …… kW [2]

(ii) Use energy conservation to explain why the oscillations of the coil are damped.

……

……

……

……[2]

END OF PAPER

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PHYSICS 9749 / 04

Preliminary Examination **29 August 2017**
Paper 4 Practical **2 hour 30 minutes**

Candidates to answer all questions in the Question Booklet.

Additional Material: Question Booklet for Question 4

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or do not use appropriate units.

Give details of the practical shift and laboratory in the boxes provided.

Shift
Laboratory

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 14
2	/ 9
3	/ 20
4	/ 12
Total	/ 55

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1 This investigation considers the angles formed by the threads in a pulley system when it is in equilibrium.

(a) In this set-up, there are two threads – a long thread AB and a short thread CD, as shown in Fig.1.1. Two pulleys P and Q are identical.

Tie end A to the 100 g mass.

Pass the thread AB through pulleys P and Q.

Tie end B to the 50 g mass.

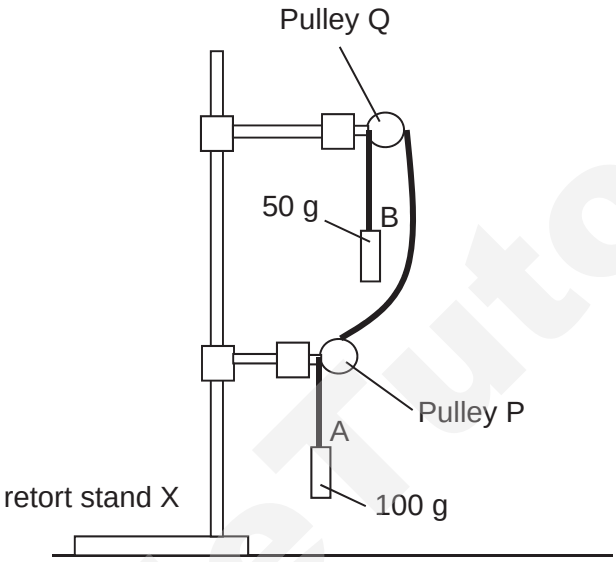

Fig.1.1

(b) Tie thread CD as shown in Fig.1.2. **Thread CD must be kept horizontal** throughout the whole experiment.

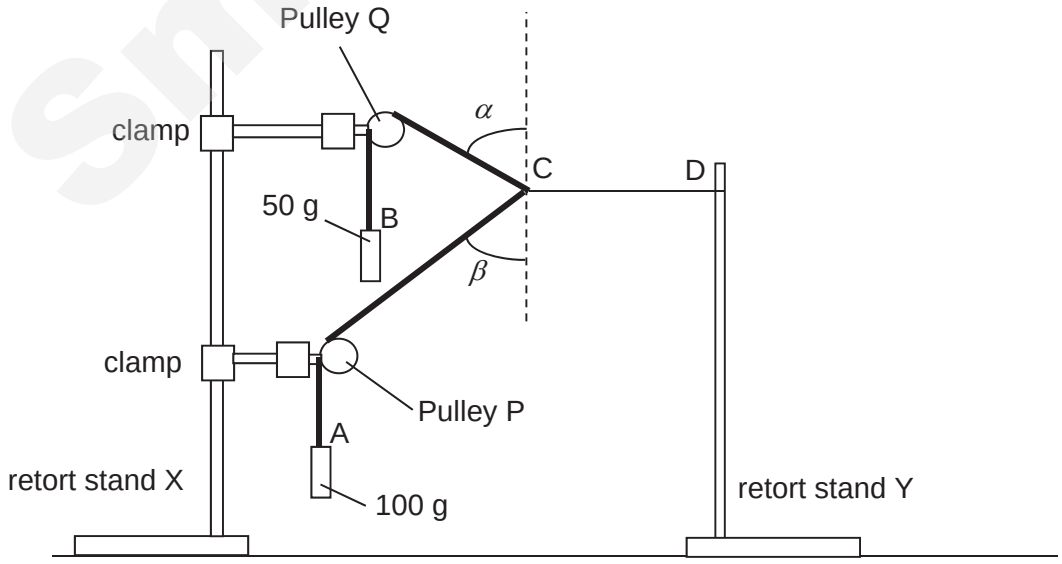

Fig.1.2

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(c) Measure the angles α and β.

α = ……

β = …… [1]

(d) Estimate the percentage uncertainty in α.

percentage uncertainty in α = …… [1]

(e) State one significant source of error that may have affected the accuracy of the readings of angles α and β.

……

……

……[1]

(f) Suggest one improvement that could be made to the experiment to address the error identified in **(e).** You may suggest the use of other apparatus or a different procedure.

……

……

……[1]

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(g) It is suggested that cos α is directly proportional to cos β. Move the retort stand Y to the right and adjust thread CD so that it is horizontal. Obtain one more set of values of α and β to investigate this suggestion. State and explain whether you agree with this suggestion.

Present your measurements and calculated results clearly. Plotting of graph is not required.

……

……

……

……

……

……[6]

(h) Let the tensions in CA, CB and CD be T_1, T_2, and T_3 respectively.

By considering the equilibrium of forces acting at point C, write two equations relating T_1, T_2, T_3, α and β. [2]

(i) A student suggests that when there is an increase in the ratio of the mass hung at end A to the mass hung at end B of thread AB, the ratio of cos α to cos β would increase. Suggest how you would verify this.

……

……

……

……[2]

[Total: 14 marks]

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2 In this experiment, you will measure the potential difference across resistor R_2 as the resistance of the circuit is varied.

(a) The Digital Multimeter (DMM) is used as a voltmeter.

Ensure that the black lead of the Digital Multimeter (DMM) is connected to the "COM" jack input, while the red lead is connected to the "V / Ω / mA" jack input.

Set the dial on the DMM to "**20 V**" mark in the "V" range.

(b) Set up the circuit as shown in Fig. 2.1. Connect one R_1 to the circuit and close the switch.

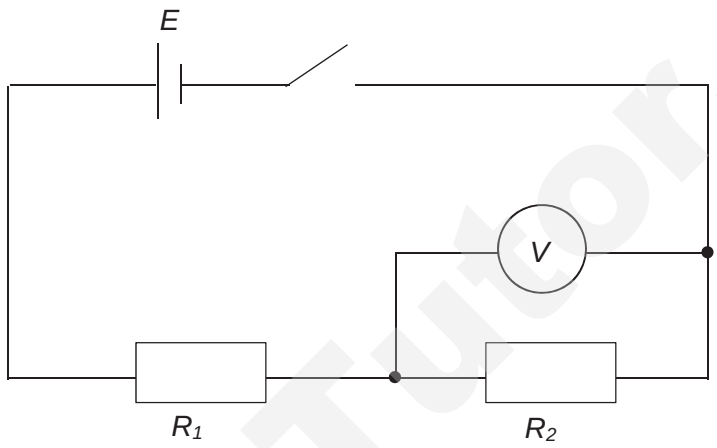

Fig. 2.1

(c) Record the potential difference across R_2, V using the voltmeter.

V = …….. [1]

(d) Change n, the number of resistor R_1 connected **in parallel**. Obtain three further sets of values for n and the corresponding values of V. [3]

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(e) Theory suggests that V and n are related by the equation

$$\frac{1}{V} = \frac{R_1}{nER_2} + \frac{1}{E}$$

where E is the e.m.f. of the power supply.

Suggest how you would determine the ratio of $\frac{R_1}{R_2}$ without measuring the resistance of the resistors directly.

……

……

……

……

……[3]

(f) In the specification of a resistor, "tolerance" refers to the percentage error in the resistance of the resistor. The tolerance of each resistor that you use in this experiment is $\pm 5\%$, resulting in an absolute error of ΔR_1 for the resistance R_1, and ΔR_2 for the resistance of R_2.

Explain how the absolute error in the effective resistance of the circuit would change when a few R_1 are connected in series instead of being connected in parallel.

……

……

……

……

……[2]

[Total: 9 marks]

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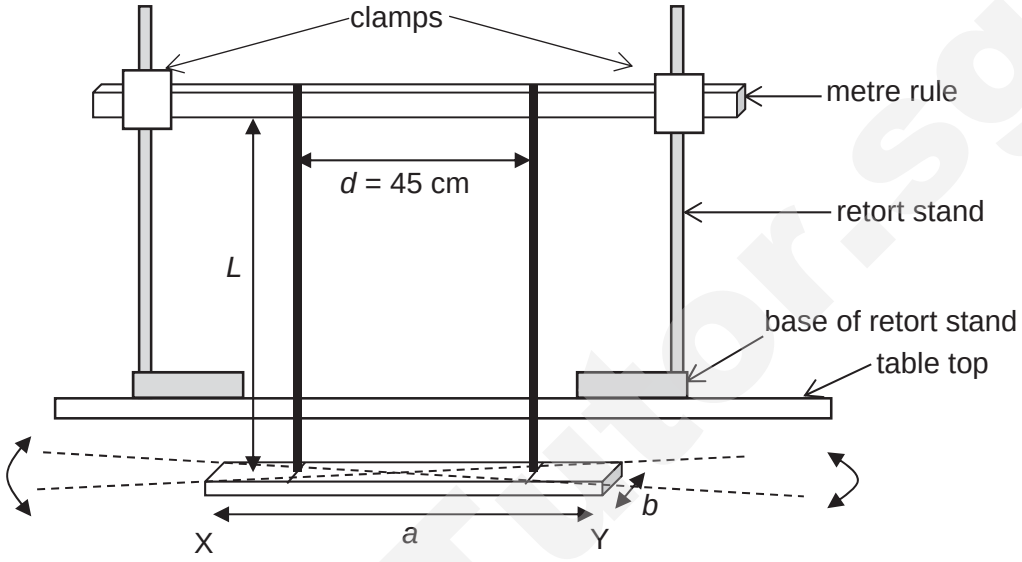
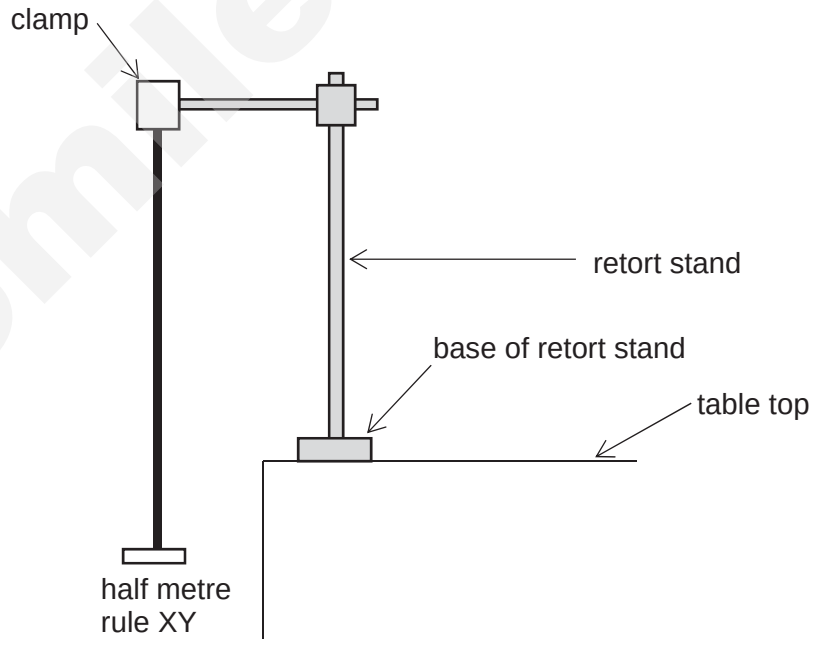
3 In this experiment, you will investigate how the period of oscillation T of a suspended half-metre rule about a vertical axis through its centre, is related to its separation L from a horizontal metre rule.

(a) Suspend a half-metre rule XY symmetrically by two exactly equal lengths of threads. XY has a length of a, and a width of b. Fig.3.1 shows the front view and Fig.3.2 shows the side view of the set up.



Front view
Fig.3.1



Side view
Fig.3.2

(b) Arrange the threads at a distance d of 45 cm apart.

(c) Ensure that the threads are vertical. Adjust L to about 100 cm.

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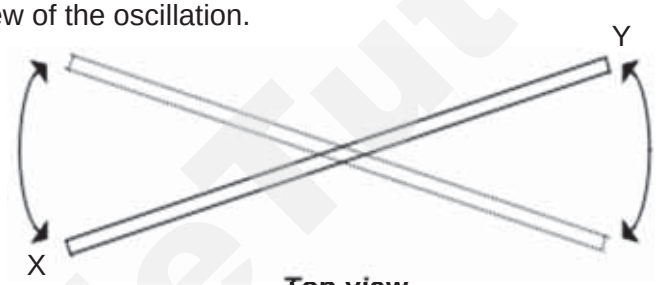
(d) Measure and record L.

L = ... [1]

(e) Estimate the absolute uncertainty in this value of L.

absolute uncertainty = ... [1]

(f) Give the suspended half-metre rule XY an angular displacement about a vertical axis through its centre, and set it into small angular oscillation as shown in Fig.3.1. Fig.3.3 shows the top view of the oscillation.



Top view
Fig. 3.3

(g) Determine the period T of the oscillations.

T = ... [1]

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(h) Vary *L* and repeat **(f)** and **(g)** to obtain further sets of values for *L* ranging from 20.0 cm to 100.0 cm, and the corresponding values of *T.* [7]

(i) It is suggested that *T and L* are related by the equation

$$g = \frac{16\pi^2(a^2 + b^2)}{12d^2}\frac{L}{T^2}$$

Plot a suitable graph and hence determine the acceleration due to gravity, *g*. [6]

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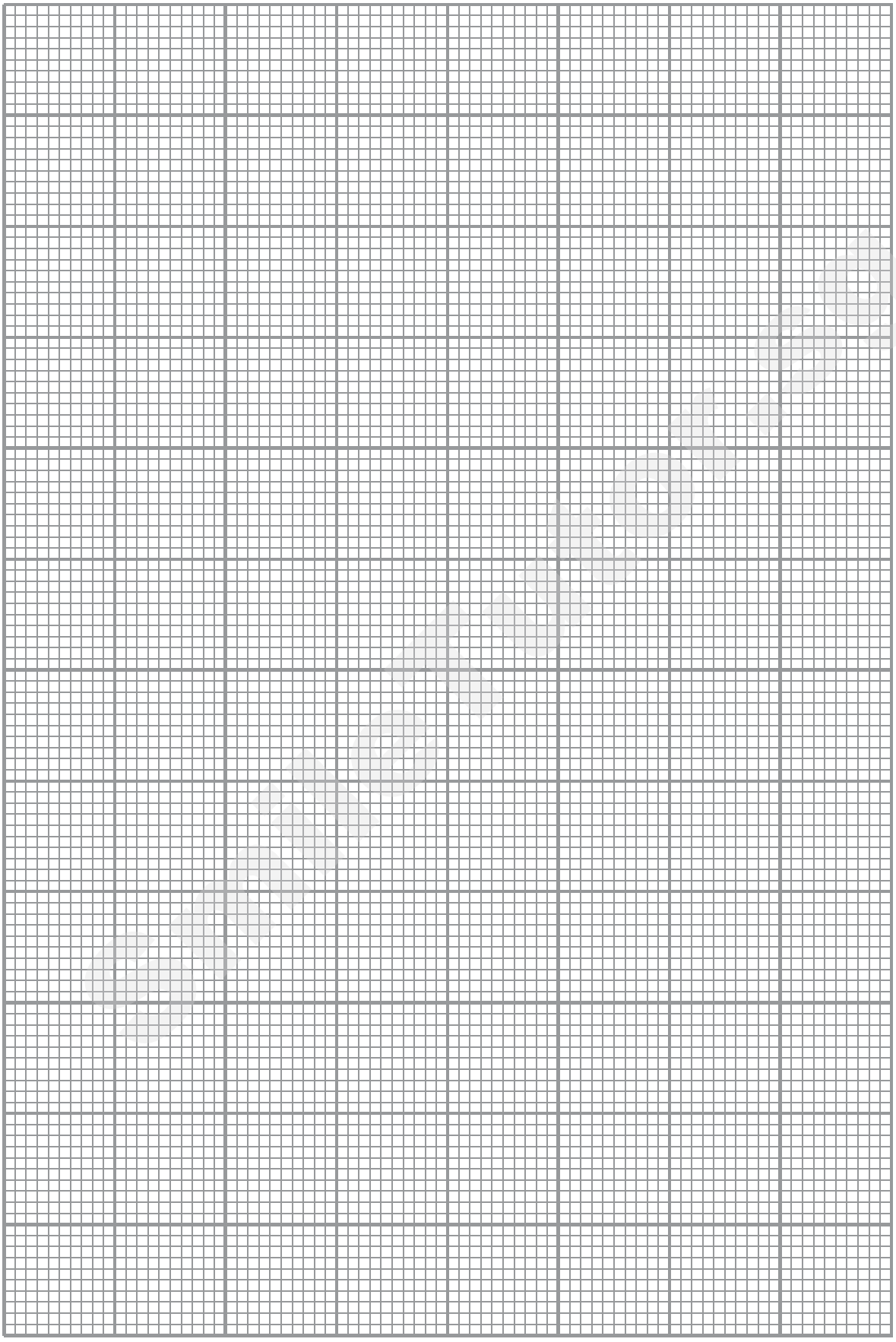

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(j) Comment on any anomalous data or results you may have obtained. Explain your answer.

……

……[1]

(k) State one significant source of error in this experiment.

……

……

……[1]

(l) Suggest one improvement that could be made to the experiment to address the error identified in **(k)**. You may suggest the use of other apparatus or different procedures.

……

……

……[1]

(m) On the graph grid on page 10, sketch a second graph to represent the results if the distance between two threads *d* is increased. Label this graph Z. [1]

[Total: 20 marks]

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PHYSICS 9749 / 04

Preliminary Examination **29 August 2017**
Paper 4 Practical **2 hour 30 minutes**

Question Booklet for Question 4

Candidates to answer all questions in the Question Booklet.

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or do not use appropriate units.

Give details of the practical shift and laboratory in the boxes provided.

Shift
Laboratory

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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4	/ 12
Total	/ 12

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4 The history of solar energy is as old as humankind. In 1954, some scientists in the United States produced electricity from the sun. They invented photovoltaic cells, which capture the sun's energy and convert it into electricity. A photovoltaic cell is an electric cell made from two layers of different materials that can produce an electric current when light of certain frequencies shines on the cell. A solar panel is a collection of photovoltaic cells.

The frequency of the light falling on the solar panel can be varied by placing different colour filters in front of the light source as shown in Fig.4.1.

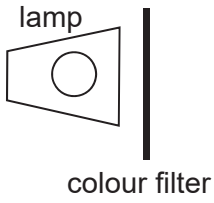

Fig.4.1

Design an experiment to investigate how the power generated by a solar panel depends on the frequency of the light falling on it.

The equipment available includes the following:

Solar panel	Resistors
Colour filters	Switch
Lamp	Stopwatch
Spectrometer with diffraction grating	Rule
Ammeter	Micrometer screw gauge
Voltmeter	

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the frequency of the light used is to be measured,
(d) how the power generated by the solar panel is to be measured,
(e) the control of variables,
(f) any precautions that would be taken to improve the accuracy, precision and safety of the experiment.

Diagram

[Total: 12 marks]

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END OF PAPER

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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME			
CG		**INDEX NO.**	

PHYSICS 9749/01

Preliminary Examination **21st Sep 2017**
Paper 1 Multiple Choice **1 hour**

Additional Materials: OMS.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in soft pencil on the OMS.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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For Examiners' Use	
MCQ	/ 30

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For Examiner's Use

DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Answer all questions.

1 Four students conducted an experiment to determine the value of g, acceleration of free fall. The values obtained by the students are as shown in the table.

Student	g_1 / m s^{-2}	g_2 / m s^{-2}	g_3 / m s^{-2}	g_4 / m s^{-2}
P	9.40	9.80	9.55	9.65
Q	9.80	9.60	9.90	10.06
R	10.10	9.90	10.15	9.85
S	9.45	9.48	9.52	9.55

If the correct value of g is 9.82 m s^{-2}, which of the students has/have the largest systematic and random errors in their experiments ?

	Largest systematic error	Largest random error
A	Q	P
B	P	Q
C	Q	S
D	S	Q

Ans : D

Student	Mean	Range
P	9.60	0.4
Q	9.84	0.46 (biggest range)
R	10.0	0.3
S	9.50 (biggest diff to correct value of 9.82 m s $^{-2}$)	0.1

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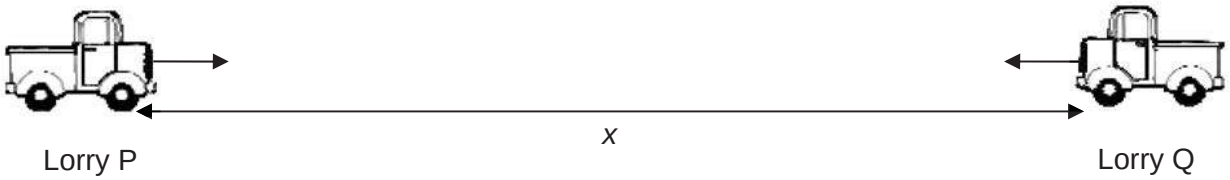
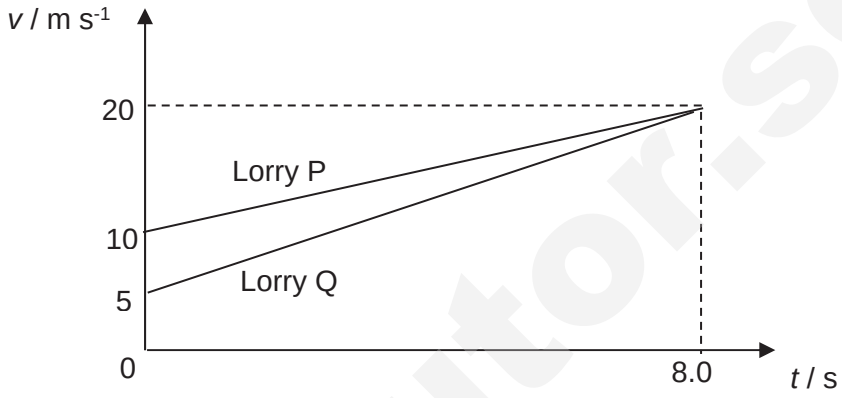
2 Lorry P and Lorry Q are initially at a distance x metres apart and are travelling in the opposite directions as shown below.



The graph shows the variation with time t of the speeds v of Lorry P and Lorry Q respectively.



At t = 8.0 s, the two lorries are 40 m apart. What is x?

A 60 m **B** 120 m **C** 220 m **D** 260 m

Answer: D

Distance travelled by Lorry P + Distance travelled by Lorry Q + 40 = x

$$\frac{1}{2}(10+20)(8.0)+\frac{1}{2}(5+20)(8.0)+40=x$$

$$x = 260 \text{ m}$$

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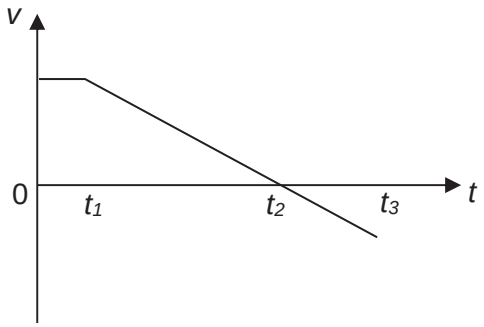
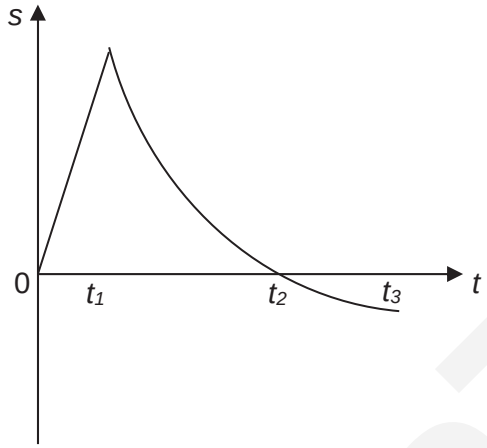
3 The graph shows how the speed v of an object varies with time t.

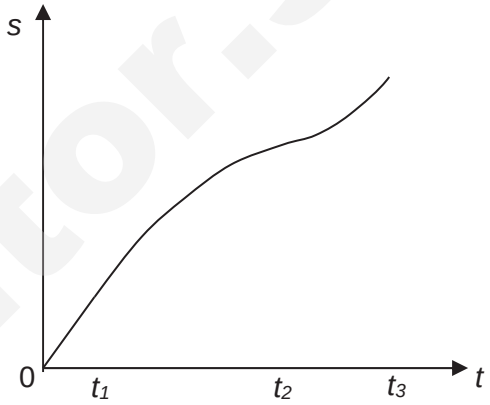


Which graph represents the variation the displacement s travelled by the object with time t?

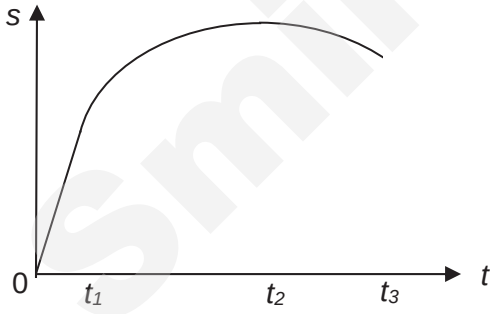
A



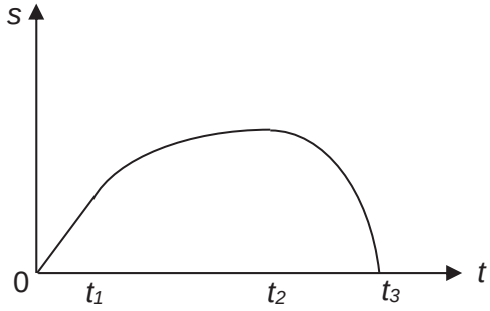
B



C



D



Answer: C
The area under v-t graph represents the change in displacement.

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4 A jet of water of density 1000 kg m^{-3} leaves the nozzle of a hose of radius 2.0×10^{-2} m. The water is directed perpendicularly to the wall at a speed of 0.50 m s^{-1}. Assume that the water does not rebound.

What is the force exerted on the wall by the water?

A 0.314 N **B** 0.628 N **C** 1.27 N **D** 15.7 N

Answer: A

Force by wall on water $= \langle F_{net} \rangle = mass\ per\ unit\ time \times \Delta v$

$$= \frac{m}{\Delta t}\Delta v = \frac{\rho(Vol)}{\Delta t}\Delta v \qquad since\ m = \rho(Vol)$$

$$= \frac{\rho \times \pi r^2 L}{t}\Delta v$$

$$= \rho \times \pi r^2 v \Delta v$$

$$= \rho \pi r^2 v(0 - v)$$

$$= -\rho \pi r^2 v^2$$

$$= -1000\pi(2.0 \times 10^{-2})^2 (0.50)^2$$

$$= -0.314 \text{ N}$$

By Newton's 3rd Law, Force by water on wall = Force by wall on water = 0.314 N

5 An astronaut falls vertically from a space vehicle and hops on the moon. The following statements are about the forces acting while the astronaut is in contact with the surface of the moon.

Which statement is correct?

A The force that the astronaut exerts on the moon is always equal to the weight of the astronaut.

B The force that the astronaut exerts on the moon is always less than the weight of the astronaut.

C The weight of the astronaut is always equal in magnitude and opposite in direction to the force that the moon exerts on the astronaut.

D The force that the astronaut exerts on the moon is always equal in magnitude and opposite in direction to the force the moon exerts on the astronaut.

Answer: D
Newton's third law

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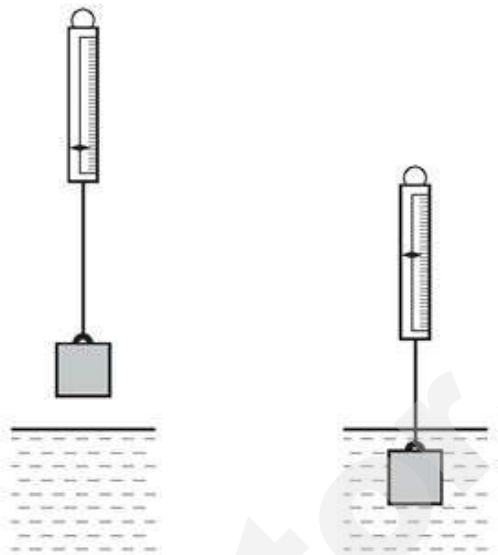
6 The diagram shows a metal cube suspended from a spring balance before and during immersion in water.

A reduction in the balance reading occurs as a consequence of the immersion.



Which statement is correct?

A The balance reading will be further reduced if the cube is lowered further into the water.

B The balance reading during immersion corresponds to the upthrust of the water on the cube.

C The forces acting on the vertical sides of the cube contribute to the change in the balance reading.

D The balance reading during immersion will be increased if the water is replaced by oil.

Answer: D
Balance reading = W – U
Density of oil is less than the density of water, therefore the upthrust experienced by the cube when it is immersed in oil is less than when it is immersed in water. Therefore the balance reading increases when water is replaced by oil.

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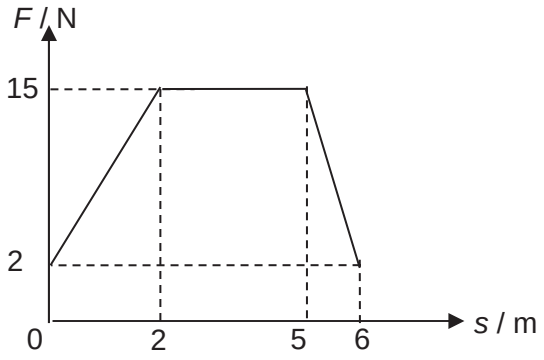
7 A student pushes a box from rest along a rough floor with constant friction of 2.0 N.

The graph shows the variation of the force exerted by the student on the box with displacement.



The final speed of the box after travelling 6 m is 5.0 m s^{-1}.

What is the mass of the box?

A 4.68 kg **B** 5.64 kg **C** 23.4 kg **D** 28.2 kg

Answer: A
Using Work-energy theorem,
Net work done = Gain in KE

Work done by $F_{net} = KE_f - 0$

$$\frac{1}{2}(3+6)(13) - 2.0(6) = \frac{1}{2}m(5.0)^2 - 0$$

$$m = 4.68 \text{ kg}$$

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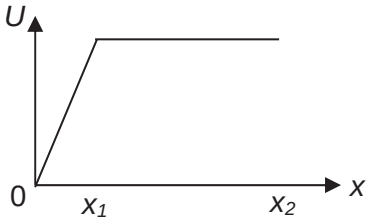
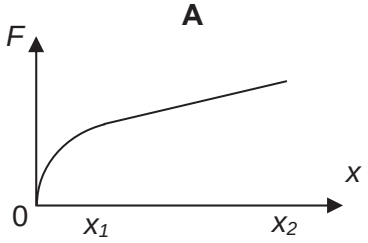
8 The graph how the potential energy U of an object varies with displacement x.

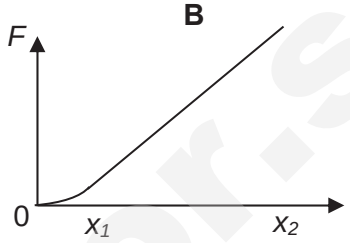


Which of the following graphs represents the variation of force acting on the object with displacement x?

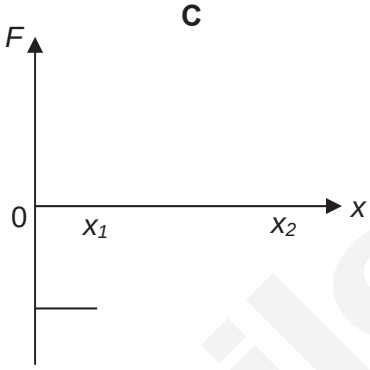
A



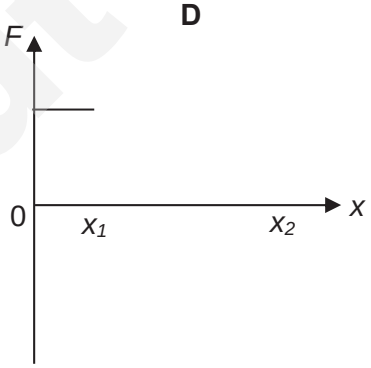
B



C



D



Answer: C
Using $F = -dU/dx$, the graph of F - x will be the negative of potential gradient.

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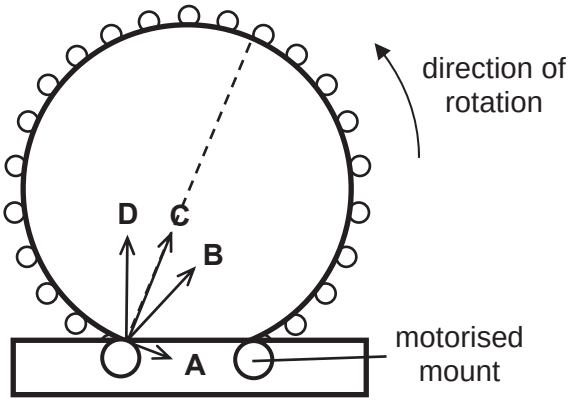
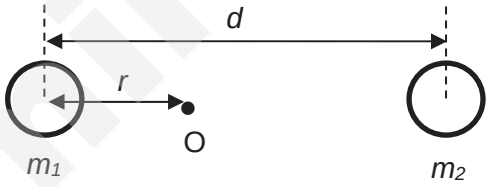
9 The Singapore Flyer wheel is supported at two points on the bottom by motorised mounts which cause it to rotate anticlockwise with constant angular velocity.



Which of the labelled arrows shows the direction of the force exerted by the motorised mount on the wheel just as it starts to turn?

Ans: **B**
There is normal contact force providing centripetal force for circular motion (indicated by C), plus tangential force (for wheel to start to move from rest) in anticlockwise direction (indicated by A). Thus, resultant force is indicated by B.

10 Two planets of mass m_1 and m_2 perform circular motion about their common centre of mass O with the same angular velocity. If the mean separation between the centres of the masses is d, what is the distance from the centre of mass m_1 to the centre of mass of the system, r?



A $\frac{m_1}{m_2}d$

B $\frac{m_2}{m_1}d$

C $\frac{m_1}{m_1+m_2}d$

D $\frac{m_2}{m_1+m_2}d$

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Ans: D

Both masses should move in circular motion with the same angular velocity.

For m_1, $\frac{Gm_1m_2}{d^2} = m_1 r\omega^2$ ---- (1)

For m_2, $\frac{Gm_1m_2}{d^2} = m_2(d-r)\omega^2$ ---- (2)

Solving (1) and (2), $r = \frac{m_2}{m_1+m_2}d$

11 The escape speed of an oxygen molecule at the Earth's surface is 1.1 x 10^4 m s^{-1}. What is the escape speed at a height of 0.2*R* above the Earth's surface, where *R* is the radius of the Earth?

A 0.5 x 10^4 m s^{-1}
B 1.0 x 10^4 m s^{-1}
C 1.1 x 10^4 m s^{-1}
D 1.2 x 10^4 m s^{-1}

Ans: **B**

By conservation of energy,
Total initial energy = Total final energy
$KE_i + PE_i = 0 + 0$
$\frac{1}{2}mv_i^2 + (-GMm/R) = 0$

$$\frac{1}{2}mv_{iR}^2 + \left(-\frac{GMm}{R}\right) = 0 + 0$$

$$v_{iR} = \sqrt{\frac{2GM}{R}}$$

$$\frac{v_{i0.2R}}{v_{iR}} = \frac{\sqrt{\frac{2GM}{(1+0.2)R}}}{\sqrt{\frac{2GM}{R}}}$$

$$v_{i0.2R} = \sqrt{\frac{1}{1.2}}(1.1\times10^4) = 1.0\times10^4 \text{ m s}^{-1}$$

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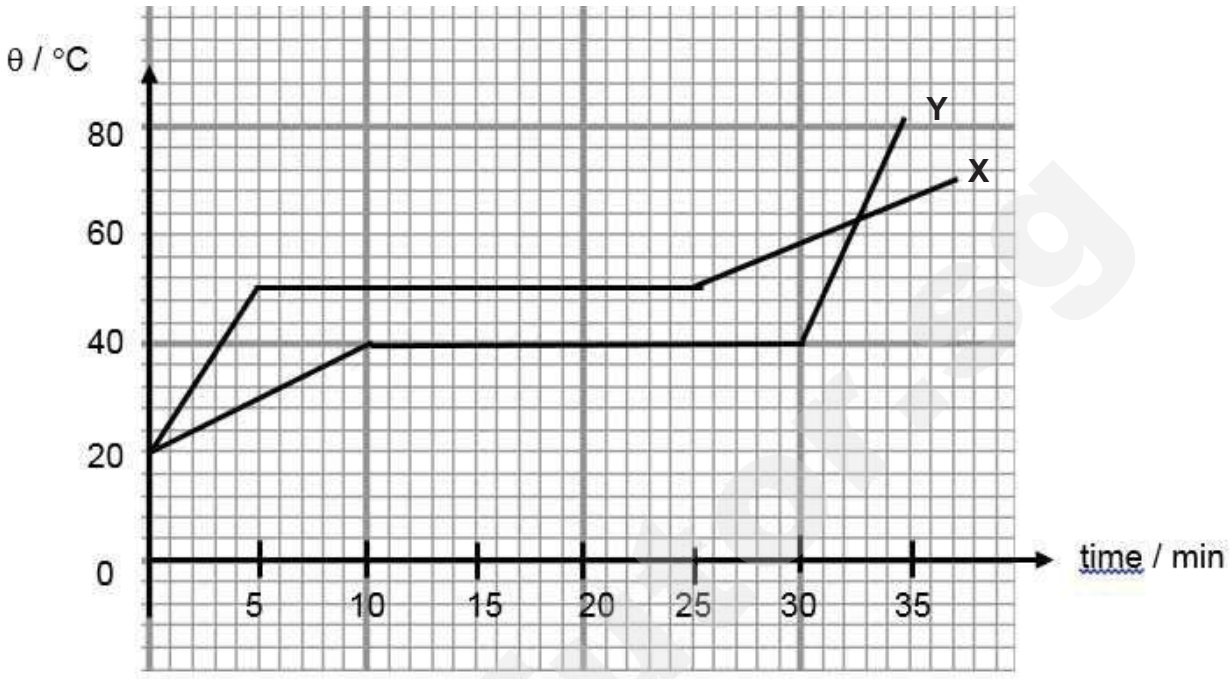
12 2.0 kg of solid X and 1.0 kg of solid Y are separately heated by two heaters of the same power. The power output of the heaters is the same throughout the whole experiment. The following graphs show the variation of the temperatures of X and Y with time.

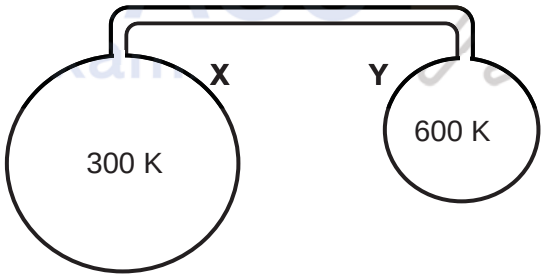


What is the ratio of the specific heat capacity of solid X to solid Y ?

A 1:3 **B** 1:6 **C** 2:3 **D** 3:2

Ans : **B**
Since power is the same,
$m_x c_x \Delta\theta_x / t_x = m_y c_y \Delta\theta_y / t_y$
$2\ c_x (30) / 5 = 1\ c_y (20)/10$
Therefore, $c_x / c_y = 1 : 6$

13 The volume of Bulb X is twice that of Bulb Y. They are filled with the same ideal gas and are connected by a narrow tube, as shown. A steady state is established with Bulb X held at 300 K and Bulb Y at 600 K. If there are *n* moles of gas in Bulb X, how many moles of gas are there in Bulb Y?



A ¼ *n* **B** ½ *n* **C** *n* **D** 2*n*

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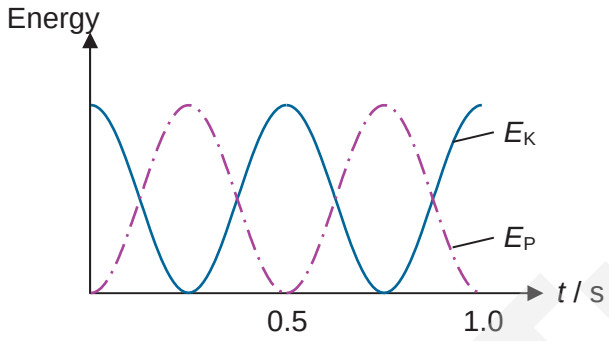
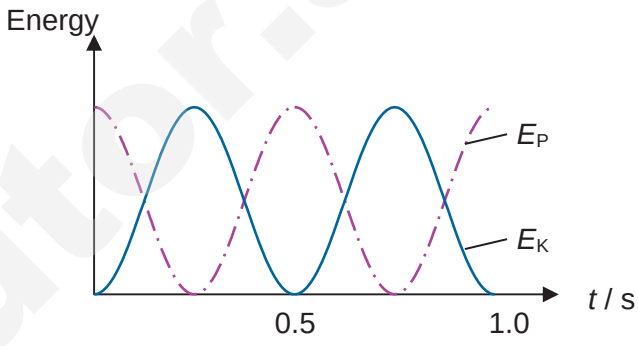
Ans : A
PV = nRT
Since gases are connected, $P_x = P_Y$
Therefore, $\frac{V_X}{V_Y} = \frac{n_X T_X}{n_Y T_Y}$
#
$$2 = \frac{n(300)}{n_Y(600)}$$
$n_Y = ¼\ n$

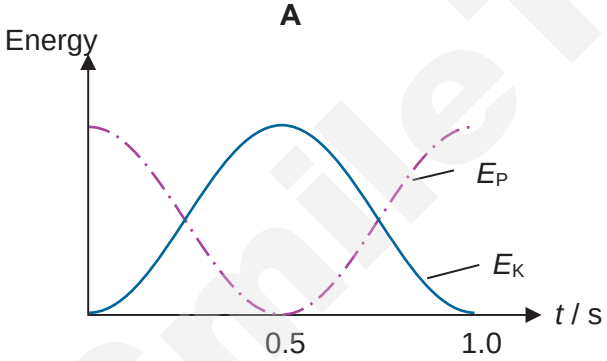
14 A certain simple pendulum swings with a period of 1.0 s. The bob of such a pendulum is given a small displacement and released at t = 0. Which diagram correctly shows the bob's kinetic energy E_K and its potential energy E_P varies with time?



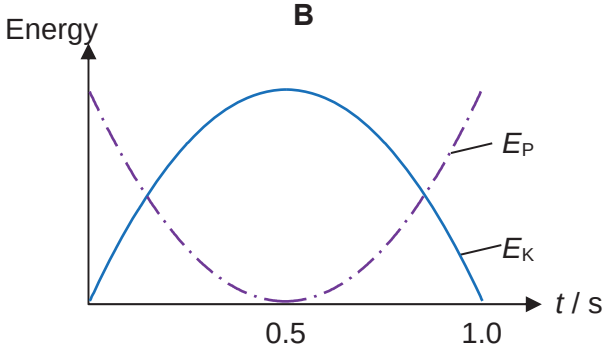
A



B



C



D

Ans : B
Eqns of the 2 graphs are given by :

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2}m\omega^2 x_0^{\ 2}\cos^2\omega t$$
$$E_P = \frac{1}{2}m\omega^2 x^2$$
$$= \frac{1}{2}m\omega^2 x_0^{\ 2}\sin^2\omega t$$

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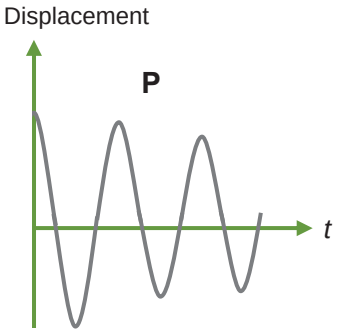
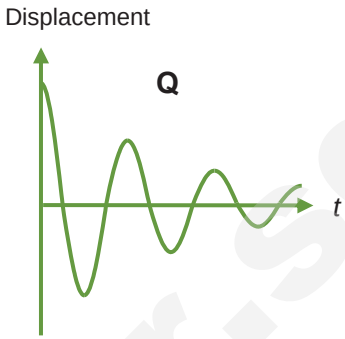
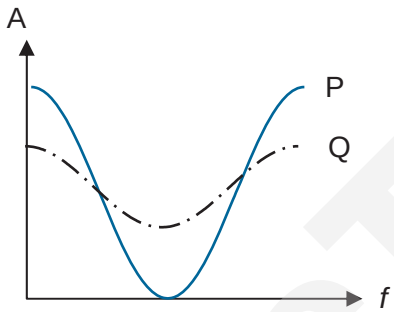
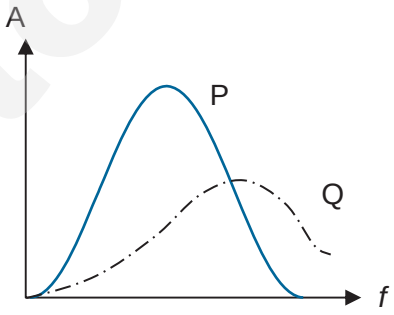
15 Two objects P and Q are given the same initial displacement and then released. The variation of their displacements with time *t* are as shown in the given graphs. The two objects are then driven by sinusoidal driving forces of the same constant amplitude and of variable frequency *f*. Which of the following graphs correctly shows how the amplitudes A of P and Q varies with *f* ?



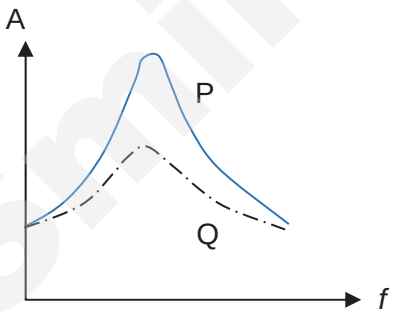




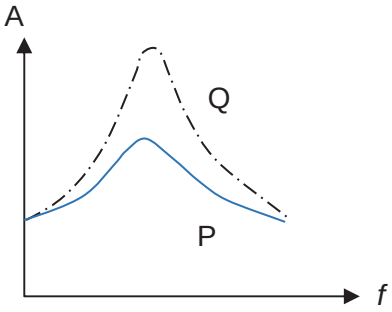
A



B



C



D

Ans : C
Amplitude-frequency graph should increase to a peak at the natural frequency and decrease thereafter. P and Q appears to have similar natural frequencies. P is lightly damped while Q has greater degree of damping. Therefore, amplitudes of P and Q will peak at similar frequencies with peak for Q lower and occurring at a slightly lower frequency.

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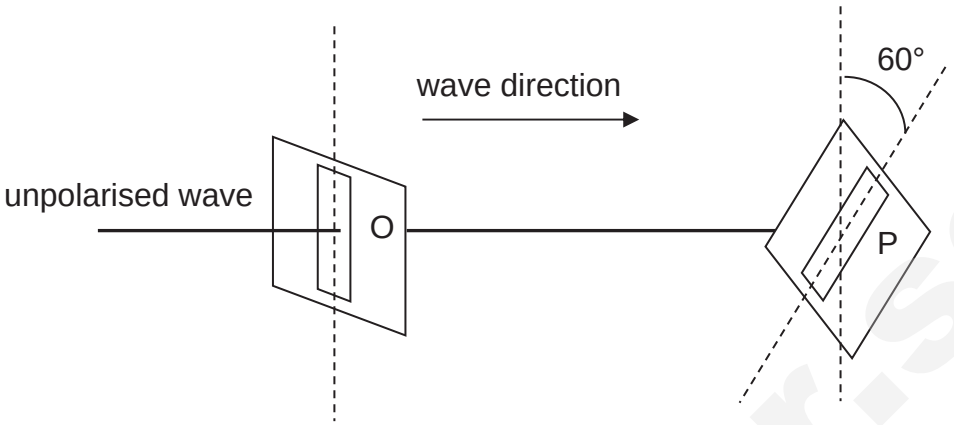
16 An unpolarised wave passes through polariser O such that the emerging wave is plane-polarized with an intensity of 2.0 W m^{-2}. A second polariser P is placed further such that the plane-polarised wave is incident normally on it. Polariser P is rotated clockwise by an angle of 60°.

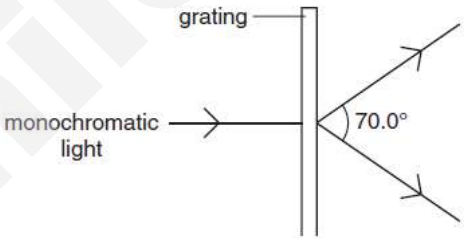


What is the intensity of the wave after passing through polariser P ?

A 0.25 W m^{-2} **B** 0.5 W m^{-2} **C** 1.0 W m^{-2} **D** 2.0 W m^{-2}

Ans : B
Using Malus' Law, $I_p = I_o \cos^2 \theta$
$= 2.0 (\cos^2 60^o) = 0.5$ W m^{-2}

17 A diffraction grating is used to measure the wavelength of monochromatic light as shown below.



The spacing of the slits in the grating is 1.00 x 10^{-6} m. The angle between the first order diffraction maximas is 70.0°.

What is the wavelength of the light?

A 287 nm **B** 470 nm **C** 574 nm **D** 940 nm

Answer: C
Using, $d \sin \theta = n\lambda$
$\lambda = (d \sin\theta) / n$
For the question, $n = 1$, $\theta = 70 / 2 = 35^o$, $d = 10^{-6}$ m,
$\lambda = (10^{-6}) (\sin 35^o) / (1)$
$= 574$ nm

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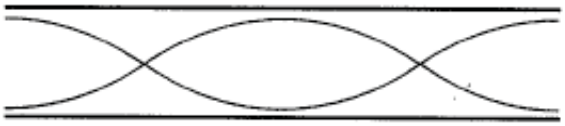
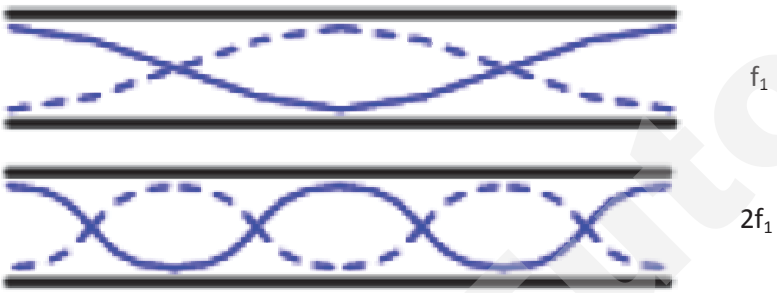
18 A stationary wave is formed in an open tube as represented in the diagram.



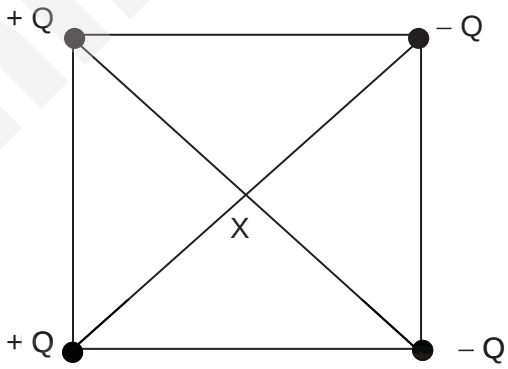
How many antinodes are formed by a stationary wave of twice the frequency?

A 2 **B** 4 **C** 5 **D** 6

Ans: C
By drawing the stationary waves that has twice the frequency of f_1, it can be counted that there are 5 antinodes.

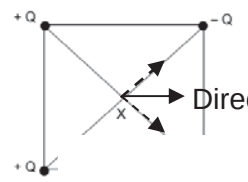


19 The diagram shows four point charges arranged in the corners of a square. What are the values of the electric field strength *E* and the electric potential *V* at a point X in the middle of the square ?



	E	*V*
A	not zero	zero
B	not zero	not zero
C	zero	not zero
D	zero	zero

Ans : **A**



Direction of resultant E

Let the distance from charge to X be r.
$V_{net} = +Q/4\pi\varepsilon r + (+Q/4\pi\varepsilon)$
$+ (-Q/4\pi\varepsilon) + (-Q/4\pi\varepsilon)$
$= 0$

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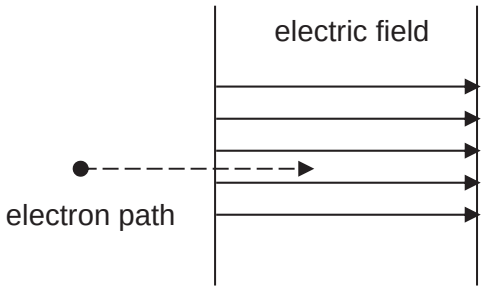
20 An electron has a de Broglie wavelength of 5.6×10^{-11} m. It enters an electric field with strength of 2.3×10^{4} V m^{-1} as shown.

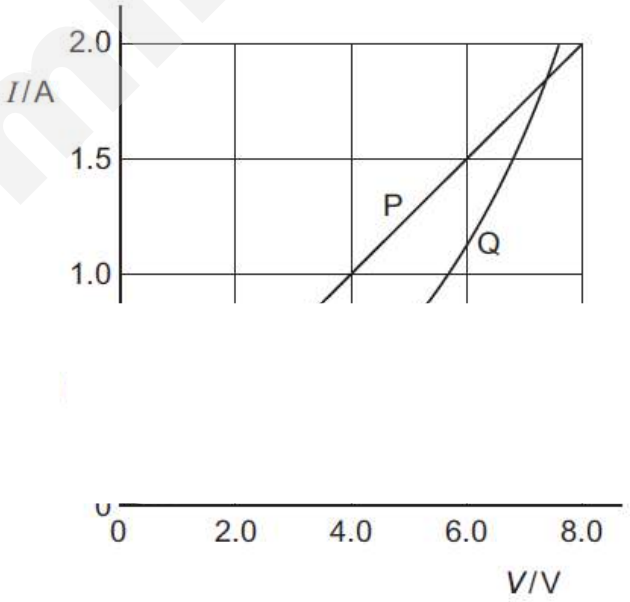


How long will it take for the electron to stop after it enters the electric field?

A 5.0×10^{-28} s **B** 2.0×10^{-15} s **C** 3.2×10^{-9} s **D** 4.2×10^{-2} s

Ans : C
$\lambda = h/p = h/mv$
Therefore, $v = h/m\lambda$ -----(1)
$F = qE = ma$
$a = qE/m$ -----(2)
Using $v = u + at$ where $v = 0$, and $u = h/m\lambda$ and $a = -qE/m$
$0 = h/m\lambda - (qE/m)\ t$
Therefore, $t = h/\lambda qE = 6.63 \times 10^{-34}/(5.6 \times 10^{-11} \times 1.6 \times 10^{-19} \times 2.3 \times 10^{4})$
$= 3.2 \times 10^{-9}$ s

21 The *I*-*V* characteristics of two electrical components P and Q are shown below.



Which statement is correct?

A P is a resistor and Q is a filament lamp.
B The resistance of Q increases as the current in it increases.
C At 1.9 A the resistance of Q is approximately half that of P.
D At 0.5 A the power dissipated in Q is double that in P.

Ans: **D**
A. Q is a thermistor.
B. Resistance of Q decreases as current in it decreases
C. At 1.9 A, the resistance
D. P = IV. When the curren at Q is double that at P.

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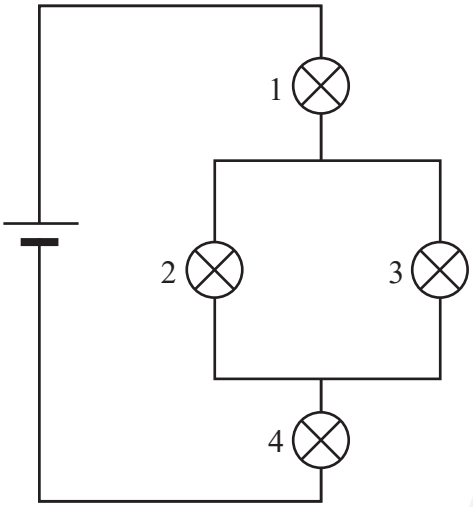
SRJ

22 An ideal cell and four identical bulbs are connected as shown.



Bulb 3 is removed. Which of the following describes the changes in the brightness of bulbs 1, 2 and 4?

	Bulb 1	Bulb 2	Bulb 4
A	dimmer	brighter	brighter
B	dimmer	brighter	dimmer
C	brighter	dimmer	brighter
D	dimmer	dimmer	dimmer

Ans: B

With bulb 3 in parallel to bulb 2, the potential difference across bulb 2 is a smaller fraction of the cell's e.m.f as compared to that of bulbs 1 and 4.

With bulb 3 removed, the potential difference across bulb 2 increases while those of bulb 1 and bulb 4 decrease correspondingly. With fixed resistance, power dissipated increases as potential increases, hence bulbs 1 and 4 became dimmer and bulb 2 became brighter.

Alternatively,

Before bulb 3 was removed,

$$R_{total} = R + \left(\frac{1}{R} + \frac{1}{R}\right) + R = 2.5R$$

$$I_{total} = \frac{V}{2.5R} = 0.4\frac{V}{R} = I_{bulb1} = I_{bulb4}$$

$$I_{bulb2} = I_{bulb3} = 0.2\frac{V}{R}$$

After bulb 3 was removed,

$$R_{total} = R + R + R = 3R$$

$$I_{total} = \frac{V}{3R} = 0.33\frac{V}{R} = I_{bulb1} = I_{bulb2} = I_{bulb4}$$

$\therefore I_{bulb1}$ and I_{bulb4} decreased, I_{bulb2} increased

since brightness $\propto$ power dissipated $= I^2R$

bulbs 1 and 4 became dimmer, bulb 2 became brighter

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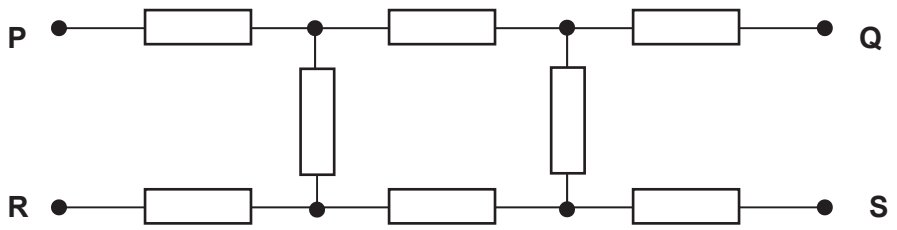
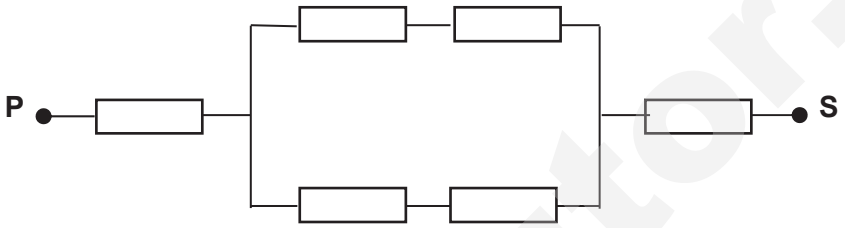
23 Each resistor has a similar resistance of 10 Ω. What is the equivalent resistance of the circuit shown in the figure below between points **P** and **S**?



A 10 Ω **B** 20 Ω **C** 30 Ω **D** 40 Ω

Ans: **C**



$R_{eff} = 10 + [1/20 + 1/20]^{-1} + 10 = 30\ \Omega$

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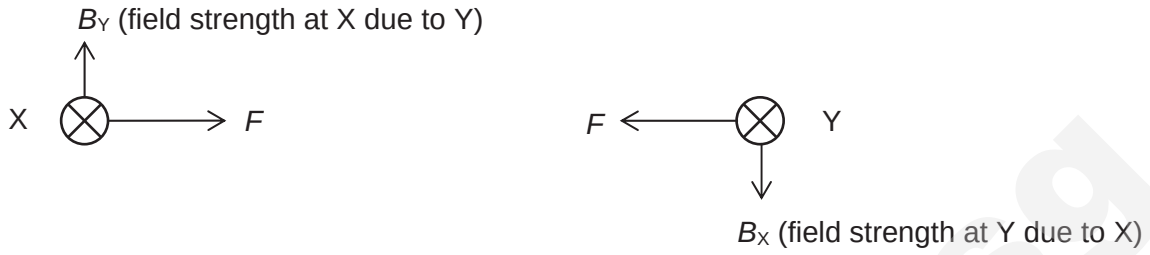
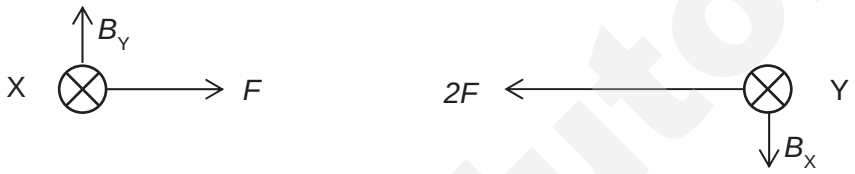
24 Two long, parallel, straight wires X and Y carry equal currents into the plane of the page as shown. The diagram shows arrows representing the magnetic field strength B at the position of each wire and the magnetic force F on each wire.



The current in wire Y is doubled. Which diagram best represents the magnetic field strengths and forces?

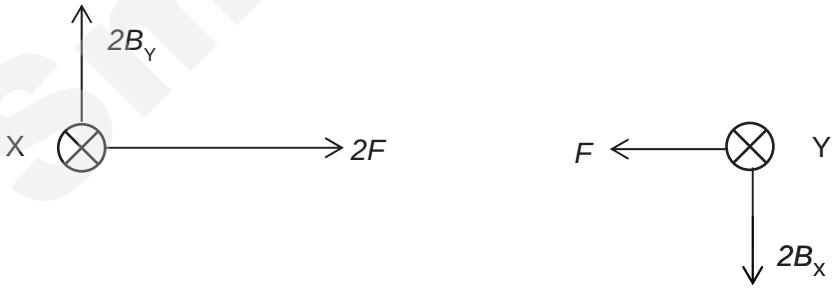
A



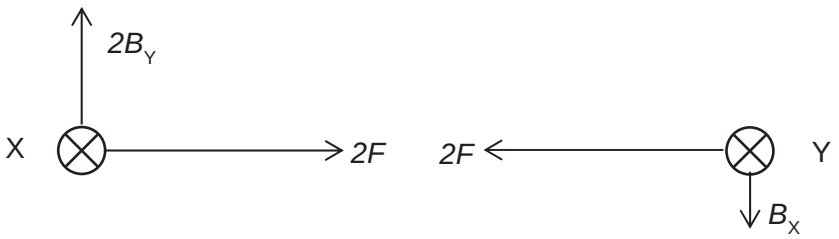
B



C



D



Ans: D

When current in wire Y doubled, field strength at X due to Y = $2B_Y$,
the magnetic force on X due to Y = $2B_Y(I)(L) = 2F$,
The magnetic force on Y due to X = $B_X(2I)(L) = 2F$, opposite in direction.
(obeying Newton's 3rd L

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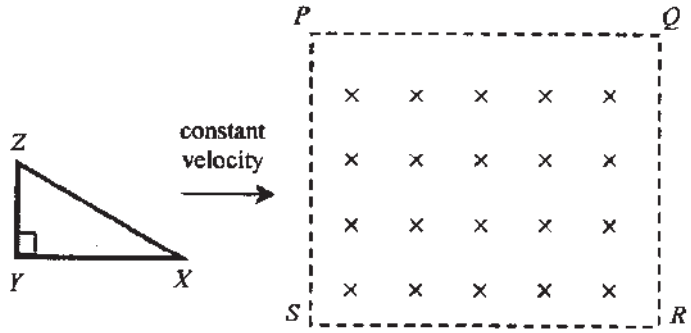
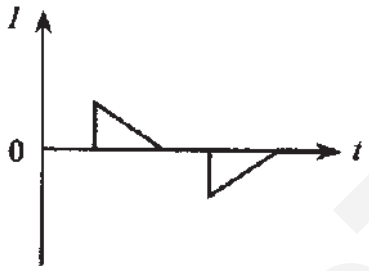
25

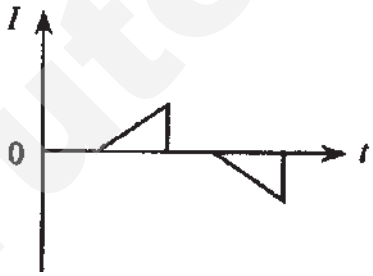


In the diagram above, *XYZ* is a small right-angled triangular metal frame moving with a constant velocity across a rectangular region *PQRS* with a uniform magnetic field pointing into the paper. Which of the following graphs best shows the variation of the current I induced in the frame with time *t*?

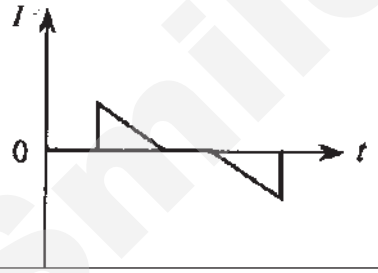
A



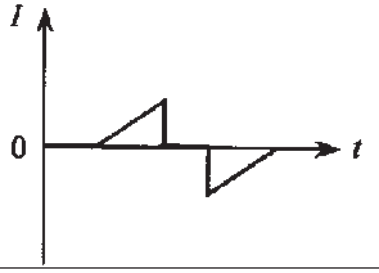
C



B



D



Ans: C

As triangle enters into magnetic field, area increases at an increasing rate, thus induced emf increases and induced current increases until the whole triangle is inside the magnetic field. As triangle exits from the magnetic field, area decreases at an increasing rate, and induced current increases to maximum until the triangle leaves the magnetic field.

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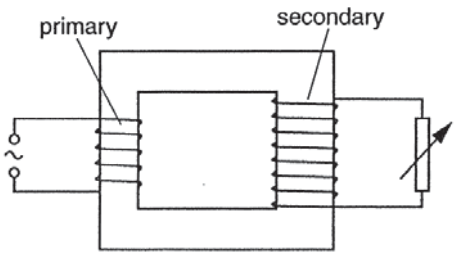
26 The primary coil of a transformer is connected to an alternating voltage supply. The secondary coil is connected across a variable resistor.



Which change will cause a decrease in the p.d. across the secondary coil?

A increasing the number of turns of the primary coil

B increasing the current in the primary coil

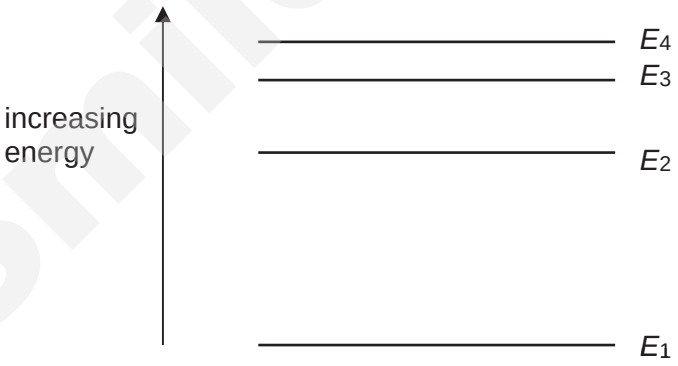
C increasing the cross-sectional area of the secondary coil

D increasing the resistance of the variable resistor

Ans: **A**

$V_s/V_p = N_s/N_p$

27 Some of the energy levels of the hydrogen atom are represented in simplified form by the given diagram which has a linear scale. The emission of blue light is associated with the transition of an electron from E_4 to E_2. Which of the following transitions could be associated with the absorption of the red light ?



A E_2 to E_3

B E_1 to E_4

C E_3 to E_2

D E_4 to E_1

Ans : A
Absorption transition is in the direction of increasing energy.
$\Delta E = hf$
Since $f_{red} < f_{blue}$, therefore $\Delta E_{red} < \Delta E_{blue}$

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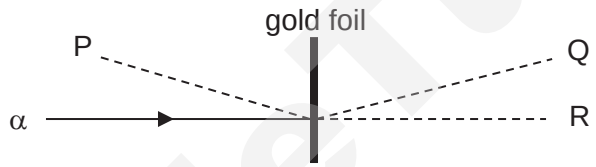
28 The momentum of a proton is measured with an uncertainty of 1.0%. Given that it has kinetic energy of 1.00 MeV, which of the following is the minimum uncertainty in its position?

A 1.1×10^{-11} m **B** 2.9×10^{-12} m **C** 1.1×10^{-12} m **D** 7.0×10^{-13} m

Ans : B
$E = p^2/2m$,
$p = \sqrt{(2mE)}$
$= \sqrt{(2 \times 1.67 \times 10^{-27} \times 1.6 \times 10^{-13})}$
$= 2.312 \times 10^{-20}$ kg m s^{-1}
Therefore uncertainty in p = $0.01 \times 2.312 \times 10^{-20}$
$= 2.312 \times 10^{-22}$ kg m s^{-1}
$\Delta x \Delta p > h$
$\Delta x > 6.63 \times 10^{-34} / 2.312 \times 10^{-22}$
$= 2.87 \times 10^{-12}$ m

29 In an experiment on α-particle scattering, α-particles are directed onto a gold foil, and detectors are placed at positions P, Q and R as shown in the diagram below.

What is the distribution of α-particles as recorded at P, Q and R respectively?



	Position P	Position Q	Position R
A	none	none	all
B	none	some	most
C	most	some	fewer than at position Q
D	fewer than at position Q	some	most

Answer: D
Majority of the α-particles managed to pass through the gold foil without being deflected since the atom consists of mostly empty space.

30 Which statement about alpha, beta and gamma radiation is correct?

A Alpha radiation has the greatest ionising power.
B Beta radiation has the greatest ionising power.
C Gamma radiation has the greatest ionising power.
D Alpha, beta and gamma radiation have nearly equal ionising powers.

Answer: A
Ionisation power
Alpha radiation > beta radiation > gamma radiation

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PHYSICS 9749/02

Preliminary Examination **11th September 2017**
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

.

For Examiners' Use	
Q1	/ 8
Q2	/ 9
Q3	/ 15
Q4	/ 9
Q5	/ 20
Q6	/ 19
Total marks	/ 80

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For Examiner's Use

DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 In order to determine the value of the gravitational acceleration g, a student throws a ball at a speed of 15 m s^{-1} horizontally from a building.

(a) The student collects the following data for the ball when it reaches the ground.

Quantity	Value	Absolute Uncertainty
Vertical displacement	122.500 m	0.002 m
Horizontal displacement	75.000 m	0.002 m

(i) Show that the time taken to reach the ground is 5.0 s. [1]

Consider the horizontal direction,

$s_x = u_x t$

$t = \dfrac{75.0}{15}$ [M1]

$= 5.0$ s

(ii) The uncertainty of the time taken is 0.4 s.

Determine the value of g, with its associated uncertainty.

Consider the vertical direction,

$s_y = u_y t + \dfrac{1}{2} g t^2 = \dfrac{1}{2} g t^2$

$g = \dfrac{2s_y}{t^2} = \dfrac{2(122.5)}{5.0^2} = 9.80$ m s^{-2} [M1]

$\dfrac{\Delta g}{g} = \dfrac{\Delta s_y}{s_y} + 2\dfrac{\Delta t}{t} = \dfrac{0.002}{122.5} + 2\left(\dfrac{0.4}{5.0}\right)$ [M1]

$\Delta g = 2$ m s^{-1} (1 s.f.)

$g \pm \Delta g = (10 \pm 2)$ m s^{-2} [A1]

g = ... ± ..... m s^{-2} [3]

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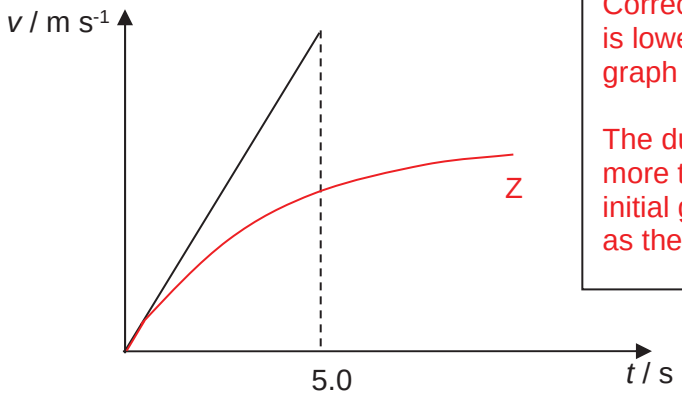
(b) In the absence of air resistance, the variation of the vertical speed v of the ball with time t is shown in Fig. 1.1.



Correct shape – a curve that is lower than the original graph [B1]

The duration of motion is more than 5.0 s, and the initial gradient is the same as the original graph [B1]

Fig. 1.1

(i) In reality, there is air resistance. Sketch the graph of variation of vertical speed with time on Fig. 1.1, and label this graph Z. [2]

(ii) Explain the shape of the graph Z.

As the ball falls downwards, its speed increases and therefore upward air resistance acting on it also increases. [B1]
The net force acting on the ball decreases, therefore the acceleration decreases, resulting in the gradient of graph Z being gentler than that of the original graph. [B1]

..... [2]

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2 Truck X of mass 22 000 kg and moving at a speed of 3.0 m s^{-1}, catches up and collides with Truck Y moving at 1.0 m s^{-1} moving in the same direction as shown in Fig. 2.1.

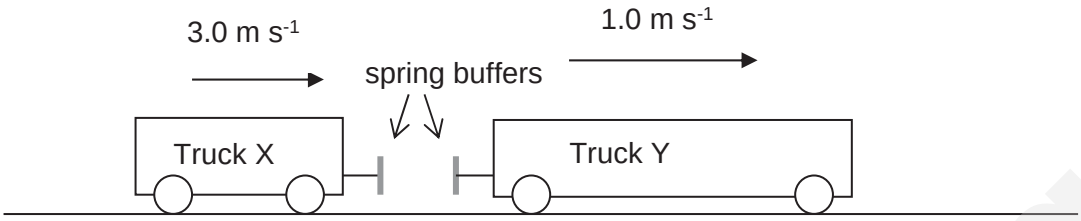

Fig. 2.1

Fig. 2.2 shows how the speeds of the trucks vary with time *t* before, during and after the collision.

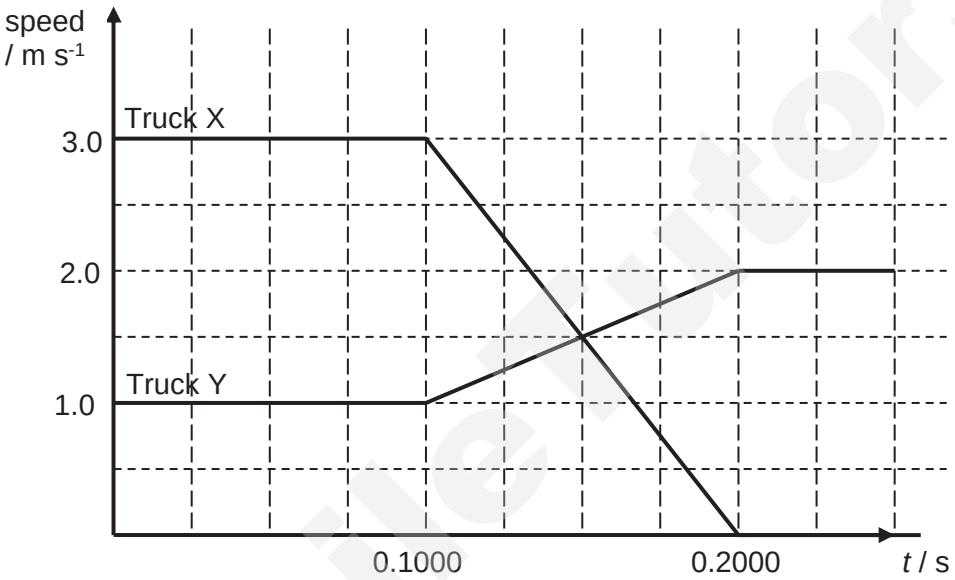

Fig. 2.2

(a) Using Fig. 2.2, show that the mass of Truck Y is 66000 kg. [1]

Using Principle of Conservation of Linear Momentum,
Total momentum before collision = Total momentum after collision
or
$m_X u_X + m_Y u_Y = m_X v_X + m_Y v_Y$
$22000(3.00) + m_Y(1.00) = 0 + m_Y(2.00)$ [M1]
$m_Y = 66000$ kg

(b) Showing your working clearly, explain whether this collision is elastic. [2]

Total kinetic energy before collision = ½ x 22000 x 3^2 + ½ x 66000 x 1^2
= 99000 + 33000
= 132 000 J
Total kinetic energy after collision = 0 + ½ x 66000 x 2^2 = 132 000 J
[M1 for both total KE before and after]
Since total kinetic energy of the system is conserved, collision is elastic. [A1]

OR

Relative speed of approach = $u_X - u_Y$ = 3 - 1 = 2 m s^{-1}
Relative speed of separation = $v_Y - v_X$ = 2 – 0 = 2 m s^{-1}
[M1 for both RSA and RSS]
Since the speed of ap , collision is elastic.[A1]

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(c) (i) State the time at which the trucks are closest to each other.

At 1.500 s, when the relative speed is 0 m s^{-1}.

t = …… s [1]

(ii) 1. Calculate the total kinetic energy of the two trucks at the time stated in **(c)(i).**

At 1.500 s,

$$\text{Total KE} = \frac{1}{2}m_X v_X^{\,2} + \frac{1}{2}m_Y v_Y^{\,2}$$

$$= \frac{1}{2}(22000)(1.5)^2 + \frac{1}{2}(66000)(1.5)^2$$ No ecf from (c)(i)

$$= 99000 \text{ J}$$ [A1]

total kinetic energy = …… J [1]

2. Hence, calculate the maximum elastic potential energy stored in the spring buffer during the collision.

Using Principle of Conservation of Energy from 0.100 s to 0.150 s,
Gain in EPE
= Loss in KE

$$= \frac{1}{2}(22000)(3.0)^2 + \frac{1}{2}(66000)(1.0)^2 - 99000$$

$$= 33000 \text{ J}$$ [A1]

OR
Using Principle of Conservation of Energy from 0.150 s to 0.200 s,
Loss in EPE
= Gain in KE

$$= \frac{1}{2}(66000)(2.0)^2 - 99000$$

$$= 33000 \text{ J}$$ [A1]

maximum elastic potential energy stored = …… J [1]

(d) (i) Calculate the magnitude of the impulse exerted by Truck X on Truck Y.

Impulse
= change in momentum of Y
= 66 000 x (2 – 1) [M1]
= 66 000 N s [A1]

magnitude of impulse = …… N s [2]

(ii) If the duration of the collision is reduced, with initial and final speed of both trucks remain unchanged, state and explain how this affects your answer in **(i)**.

The change in momentum of Truck Y remains the same since there is no change in the initial and final speeds of both trucks.
By Impulse-momentum Theorem, the impulse remains unchanged. [B1]

..
1]

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3 **(a)** State what is meant by *coherent sources*.

Coherent sources are sources that emit waves with constant phase difference. [B1]
This means that the waves have the same frequency/wavelength/speed (any 2). [B1]

……

…… [2]

(b) A stereo system in a large hall has two identical speakers, S_1 and S_2, placed 1.2 m apart as shown in Fig. 3.1. The amplitude of the output of each speaker is proportional to the potential difference across its terminals, which is adjusted by means of a balance control.

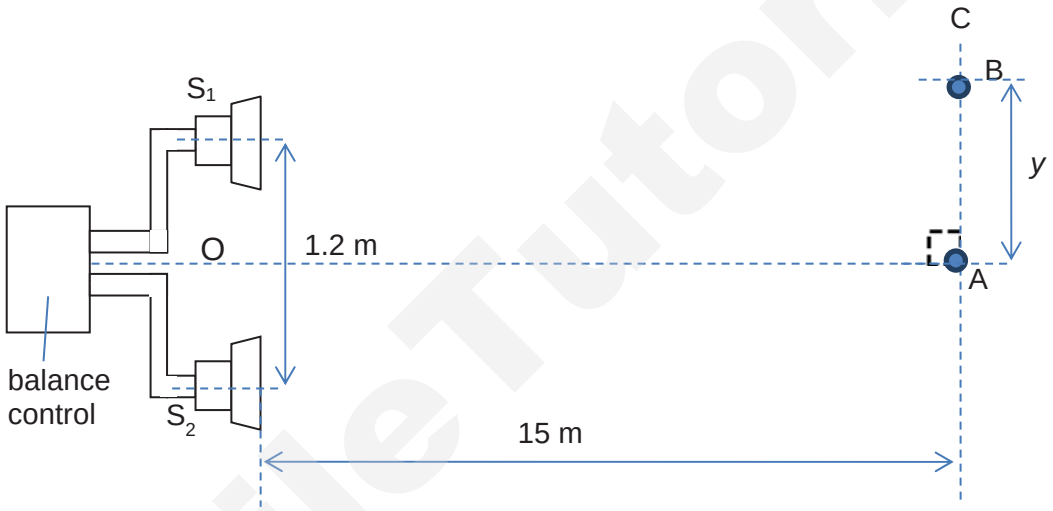

Fig. 3.1 (not to scale)

Initially, the speakers are emitting signals of frequency 1000 Hz which are in phase. The balance control is set such that the potential difference across the terminals of both speakers are the same.

Line AC is 15 m away from the speakers. An observer hears a loud sound of intensity I_{max} at A. As he moves along the line AC, 15 m away from the speakers, he observes that the intensity of the sound first falls to zero at point B, a distance *y* from A. The speed of sound in air is 330 m s^{-1}.

(i) Determine the distance *y*.

$y = 0.5\,x$ where $x = \frac{\lambda D}{a}$ [M1] and $\lambda = \frac{v}{f}$ since B is at minimum intensity.

$$y = \frac{(\frac{330}{1000})(15)}{(1.2 \times 2)}$$

y = 2.1 m [A1]

y = …… m [2]

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(ii) By calculating the path difference of the two sound waves arriving at B, determine the next higher frequency of the speaker such that point B would also be a point of zero intensity.

Since B is a point of minimum intensity, the path difference of S_1 and S_2 at point B,

$S_1B - S_2B = \frac{\lambda}{2} = \frac{0.33}{2} = 0.165\ m$ [M1]

For other wavelengths λ, point B will be at zero intensity if the path difference is $\left(n+\frac{1}{2}\right)\lambda$.

Therefore,

$\left(n+\frac{1}{2}\right)\lambda = 0.165m$ where n = 1 [M1]

$\lambda = 0.11m$

Using $f = \frac{v}{\lambda}$,

$f = \frac{330}{\lambda}$

f = 3000 Hz [A1]

Alternatively,

For different wavelengths λ, point B will be at zero intensity if the path difference is $\left(n+\frac{1}{2}\right)\lambda$.

As frequency increases, wavelength decreases.
Hence, since path difference is unchanged [M1],

$\left(0+\frac{1}{2}\right)\lambda_0 = \left(1+\frac{1}{2}\right)\lambda_1$ [M1]

$\lambda_0 = 3\lambda_1$

Since $f = \frac{v}{\lambda}$,

$f_1 = 3f_0 = 3000Hz$ [A1]

frequency = …… Hz [3]

(iii) With the speakers emitting the original signal frequency of 1000 Hz, the balance control is now adjusted such that the potential difference across the terminals of S_1 is reduced while the potential difference across the terminals of S_2 is unchanged. Suggest and explain any changes to the sound heard at B.

A sound is now heard at B (or the intensity of the sound at B is larger). [B1]
This is because there is now a difference between the amplitudes of the sounds at B, resulting in <u>incomplete destructive interference</u>. [B1]

……

…… [2]

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(c) Monochromatic light is passed through a rectangular slit of width b of 0.20 mm. The light is observed on a screen placed 0.75 m from the slit, as shown in Fig. 3.2.

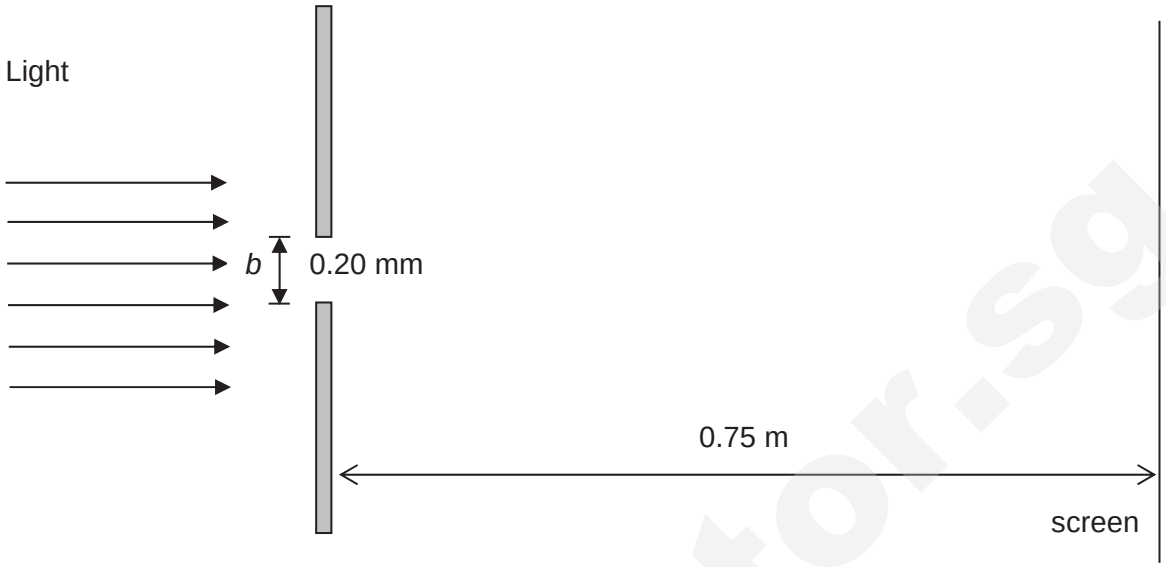

Fig. 3.2

Light passing through the slit is diffracted through an angle θ.

The variation of the intensity I of the light with the angle θ of diffraction is shown in Fig. 3.3.
The maximum value of intensity is I_0.
The angular separations between successive minima are the same.

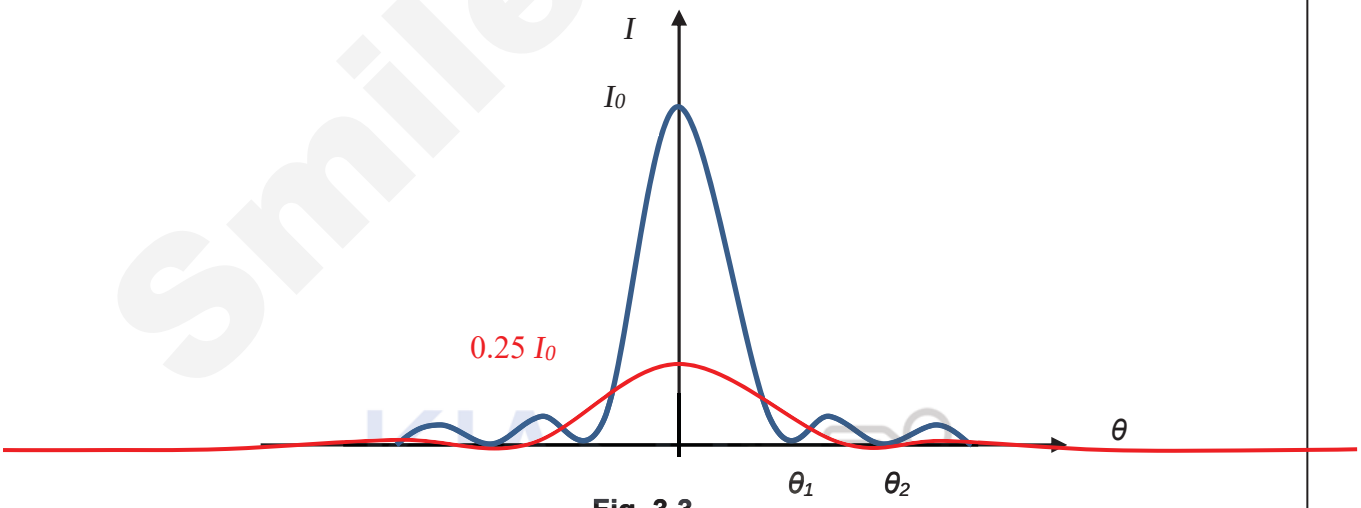

Fig. 3.3

(i) The value of θ_2, the location of the second order minima, is 0.338°.
Determine the wavelength of the monochromatic light.

$\sin\theta = \frac{\lambda}{b}$
$\lambda = b \sin \theta_1$ [M1]
$= (0.2 \times 10^{-3}) \sin (0.338°/2)$
$= 590$ nm [A1]

wavelength = …… nm [2]

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(iii) Determine the angle between two beams of light incident on the slit, each of the same wavelength as in **(i)**, such that their diffraction patterns are just resolved. Explain your working.

[B1]: 0.169°
[B1]: For patterns to be just resolved, central maximum of one beam must lie on the first minimum of the other.

angle = ……° [2]

(iii) Sketch, on the axes of Fig. 3.3, how the intensity of the light varies with θ if the slit width is halved. Label any relevant intercepts on your sketch. [2]

[B1]: Maximum intensity = 0.25 I_0
[B1]: First order minimum occurs at 0.338°.

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4 **(a)** Define the tesla.

If a straight conductor carrying a current of 1 ampere [B1] is placed at right angles to a uniform magnetic field of flux density 1 tesla [B1], then the force per unit length on the conductor is 1 newton per metre. [B1]

……

…… [3]

(b) Ions, all of the same element, are travelling in a vacuum with a speed of 9.6×10^4 m s^{-1}. The ions are incident normally on a uniform magnetic field B of flux density 320 mT. The ions follow semicircular paths A and B before reaching a sensor, as shown in Fig. 4.1.

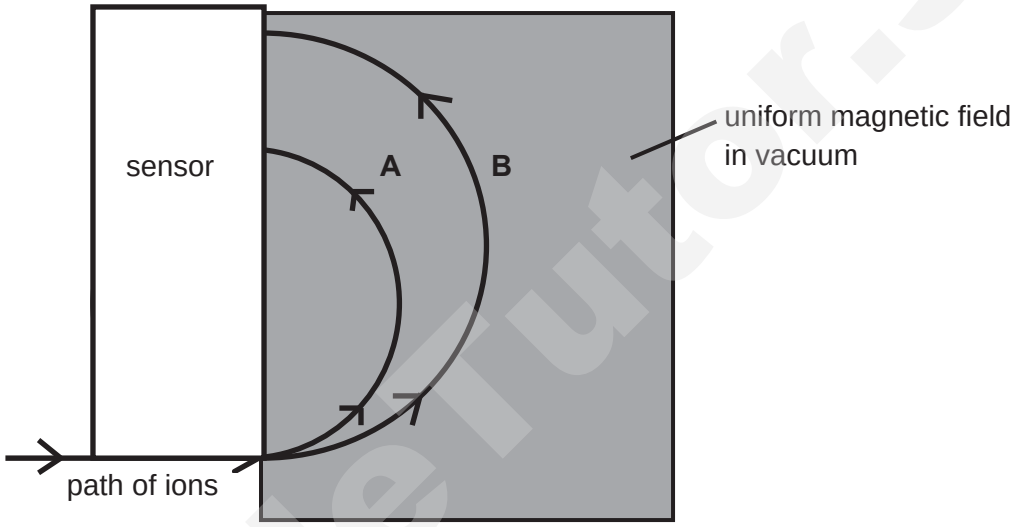

Fig. 4.1

The diameters of paths A and B are 6.2 cm and 12.4 cm respectively. The ions in path B each have charge $+1.6 \times 10^{-19}$ C.

(i) Explain why the path of the ions in the magnetic field is an arc of a circle.

The magnetic force provides the centripetal force for the ions. [B1]
It is always perpendicular to the velocity of the particle (using the Fleming's Left Hand Rule), thus it changes only the direction but not the magnitude of the velocity. [B1]
Since the particle's speed remains constant, the magnitude of the magnetic force will also remain the same, with the direction of the force towards a fixed centre of rotation/with the radius remaining the same, resulting in its path being the arc of a circle. [B1]

…… [3]

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(ii) Calculate the mass of the ions in path B.

$Bqv = mv^2/r$ [B1]
$m = Bqr/v$
$= (320 \times 10^{-3} \times 1.6 \times 10^{-19} \times 6.2 \times 10^{-2}) / (9.6 \times 10^{4})$
$= 3.31 \times 10^{-26}$ kg [B1]

mass = ……kg [2]

(iii) Explain reasons for the difference in radii of the paths A and B of the ions.

The radius of the paths depends on the mass-charge ratio of the ions, since the velocity of the ions, and the magnetic field strength is the same.
Hence, path A has a smaller radius because of the ions having the same charge but smaller mass compared to those in path B [B1].
OR
Hence, path A has a smaller radius because of the ions having the same mass but larger charge compared to those in path B [B1].

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5 **(a)** **(i)** Define *binding energy*.

Binding energy is the amount of energy required to completely separate a nucleus into its constituent nucleons such that the nucleons are infinitely far apart.

……[1]

(ii) Sketch a graph in Fig. 5.1 to show the variation of the binding energy per nucleon with nucleon number. Label the value of nucleon number and binding energy per nucleon for the isotope that has the highest binding energy per nucleon. [2]

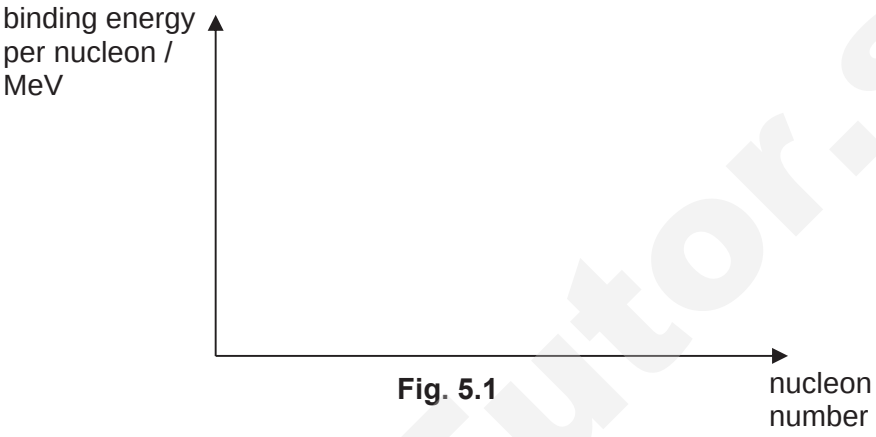
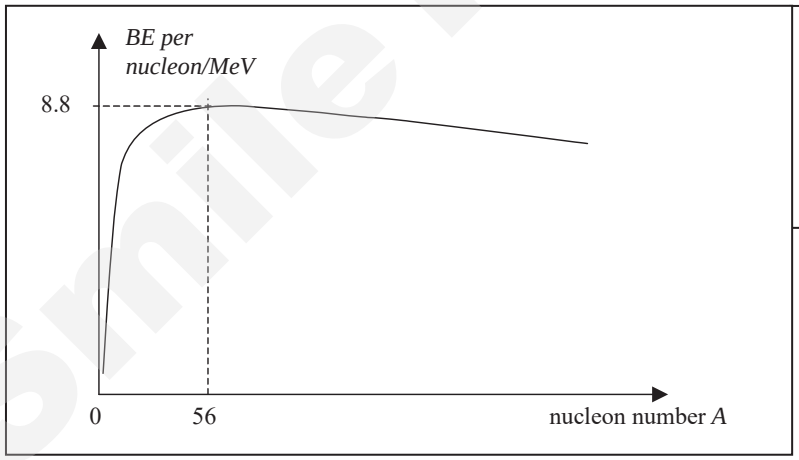


Fig. 5.1



Shape of graph [B1]

Labelling Fe-56 and the value of its BE per nucleon [B1]

(iii) With reference to your graph drawn in Fig. 5.1, explain how fission can be a potential source of energy.

In nuclear fission, a heavy nucleus splits to give two daughter nuclei of greater binding energy per nucleon. [B1]

Binding energy is the product of the binding energy per nucleon and the number of nucleons. Since the binding energy of the products is greater than the binding energy of the reactants, energy is released. [B1]

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(iv) A typical nuclear fission reaction that involves uranium-235 is represented by the equation

$$^{235}_{92}U + n \rightarrow Kr + {}^{141}_{56}Ba + 3n$$

Data for the binding energy per nucleon for the different nuclei are given in the table below:

Nuclei	Binding energy per nucleon / MeV
$^{235}_{92}U$	7.59
Kr	8.51
$^{141}_{56}Ba$	8.33

1. Deduce the number of protons and neutrons in the Kr nucleus.

No. of nucleons = 235 + 1 – 141 – 3 = 92
No. of protons = 92 – 56 = 36 [A1]
No. of neutrons = 92 – 36 = 56 [A1]

number of protons = ……

number of neutrons = ……[2]

2. Calculate the energy released in the above reaction.

Energy released = $BE_{products} - BE_{reactants}$
= 92(8.51) + 141(8.33) - 235 (7.59) [M1]
=173.8 MeV
= 173.8 x 1.6 x 10^{-13} J
= 2.78 × 10^{-11} J [A1]

energy released = …… J [2]

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(b) A stationary $^{228}_{88}\mathrm{Ra}$ nucleus undergoes beta minus decay to form an actinium isotope. The actinium isotope and beta particle move as shown in Fig. 5.2.

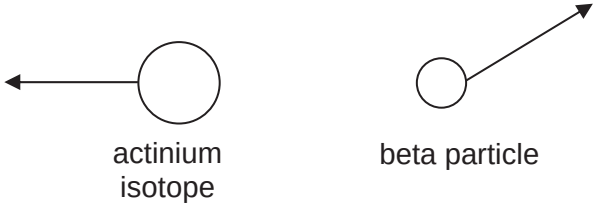

Fig. 5.2

Explain why a neutrino must also be released in this process.

Initial momentum of the Ra nucleus is zero. According to the Principle of Conservation of Linear Momentum, a neutrino with a vertical momentum that is in opposite direction to that of the beta particle must be released in order that the final momentum of the system is zero. [2]

(c) Scientists have worked out the age of the Moon by dating rocks brought back by the Apollo missions. They use the decay of potassium $^{40}_{19}\mathrm{K}$ to argon $^{40}_{18}\mathrm{Ar}$, which is stable. The decay constant of potassium-40 is 5.3×10^{-10} per year.

(i) Explain what is meant by the decay constant of potassium-40 being 5.3×10^{-10} per year.

The probability that a particular potassium-40 nucleus will decay within a year is 5.3×10^{-10}. [1]

(ii) Sketch a labelled graph on Fig. 5.3 to show how the activity of $^{40}_{19}\mathrm{K}$ changes with time if the initial activity is A_o. Mark on your graph the value of the half-life of $^{40}_{19}\mathrm{K}$. [2]

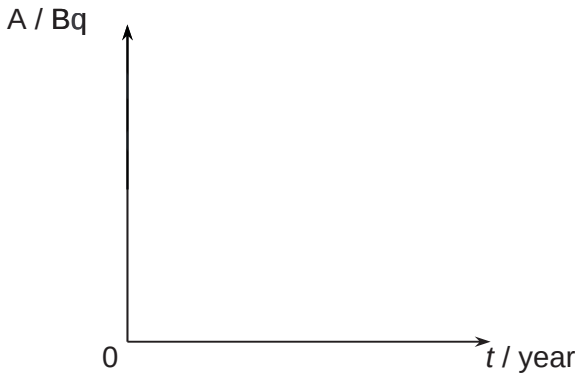

Fig. 5.3

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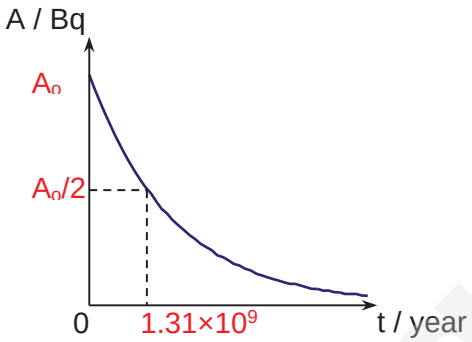
Shape [B1]

$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{5.3\times10^{-10}} = 1.31\times10^{9}$ years [B1]



(iii) In one rock sample the scientists found 0.84 μg of argon-40 and 0.10 μg of potassium-40.

1. Calculate the activity of the potassium-40 in the rock sample.

$A = \lambda N$

$= \frac{5.3\times10^{-10}}{365\times24\times60\times60}[\frac{0.1\times10^{-6}}{40}\times6.02\times10^{23}]$ [M1]

$= 0.0253$ Bq [A1]

activity = ... Bq [2]

2. Calculate the age of the rock sample in years.

$N = N_o e^{-\lambda t}$

Since molar mass is the same for both K-40 and Ar-40,

$M = M_o e^{-\lambda t}$

$0.1 = (0.1+0.84)e^{-(5.3\times10^{-10})t}$ [M1]

$t = 4.23\times10^{9}$ years [A1]

age of rock sample = ... years [2]

3. State any assumption that you have made for the calculation in **2**.

All the argon-40 is formed from the decay of potassium-40. [B1]

.....

.....[1]

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(iv) Explain why the determination of the decay constant by measuring the mass and activity of a sample is not suitable for nuclides that have relatively large decay constants.

(The activity in radioactive decay is not a constant value, but decreases with time as the number of radioactive nuclide remaining decreases.) If the decay constant is large, then the half-life is short ($T_{1/2}$ = ln2 / λ). Thus over a relatively short time of measurement, the activity and mass would not remain fairly stable. [B1]

……[1]

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6 A capacitor is an electrical device which can store charges and energy. A simple parallel plate capacitor consists of two parallel conducting plates separated by an insulator, as shown in Fig. 6.1.

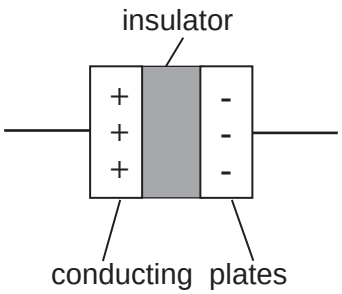

Fig. 6.1

When charged, the two plates carry opposite charges of the same magnitude. The relationship between the amount of charge stored *Q*, the potential difference *V* between the plates and the capacitance *C* is given by the equation

$$Q = CV$$

(a) Deduce the base units of C.

[Q] = [CV]
[C] = [Q] / [V] = [Q] / [W/Q] = $[Q^2]$ / [W] [M1]
= A^2s^2 / kg m^2 s^{-2} [M1]
= $A^2kg^{-1}m^{-2}s^4$ [A1]

base units = ... [3]

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(b) The capacitor is now charged. Fig. 6.2 shows the values of potential difference *V* and the corresponding amount of charge *Q*.

***V*/ V**	***Q*/ μC**
0.0	0.0
0.4	1.9
1.3	6.1
3.0	14.3
3.3	15.5
4.2	19.7
5.1	23.5

Fig. 6.2

On Fig. 6.3,

(i) plot the missing data points from Fig. 6.2. [2]

(ii) sketch the best fit line to show the variation of the amount of charge *Q* with the potential difference *V* between the plates. [1]

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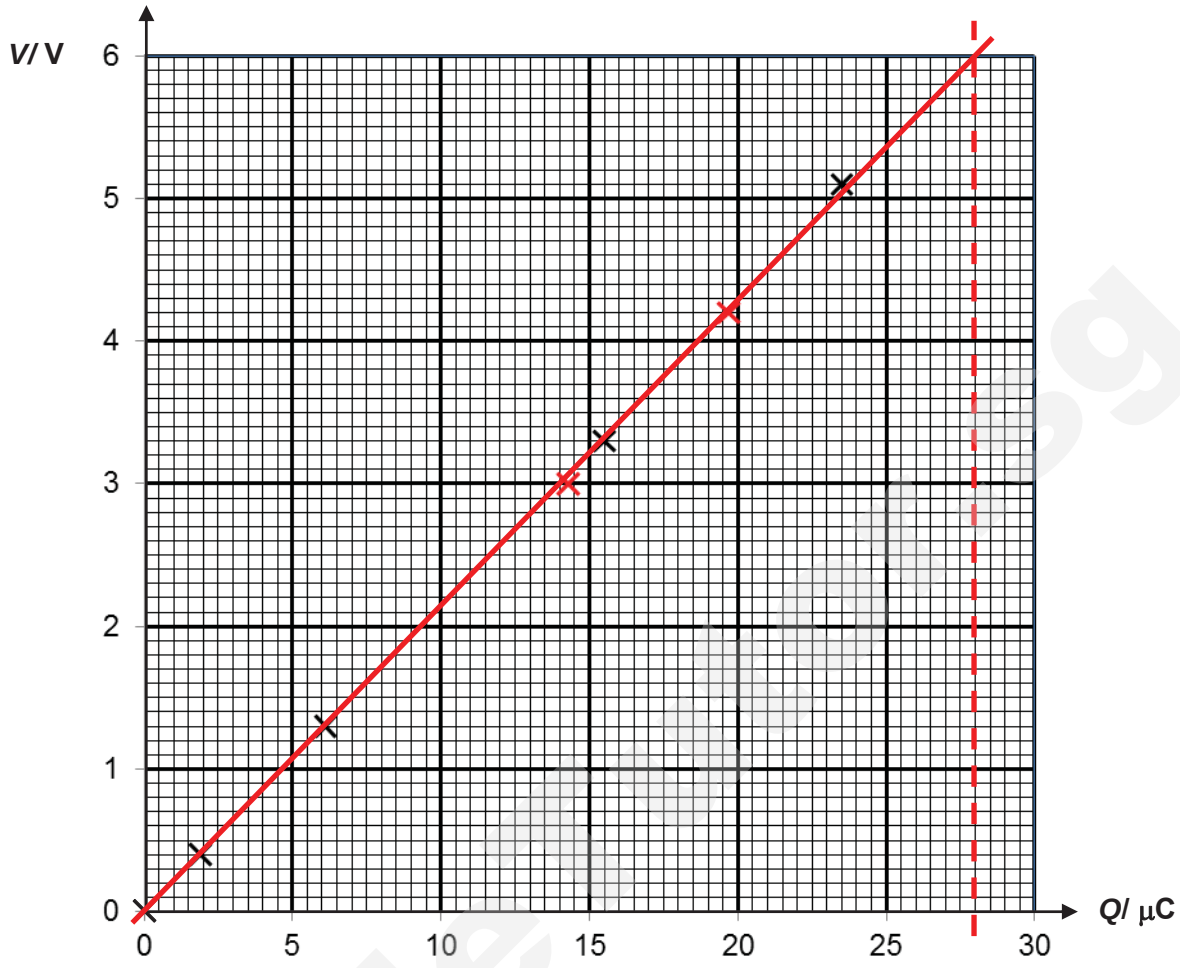

Fig. 6.3

(iii) State the quantity represented by the:

1. gradient of the graph,

1/C or reciprocal of capacitance C ..... [1]

2. area under the graph.

Electrical energy stored in capacitor ..... [1]

(iv) Hence, show that the energy E stored in a capacitor is $\frac{1}{2} CV^2$.

Area = ½ Q V [1]
= ½ CV^2

[1]

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(c) The capacitor is now discharged by connecting it across a resistor of resistance *R* as shown in Fig. 6.4.

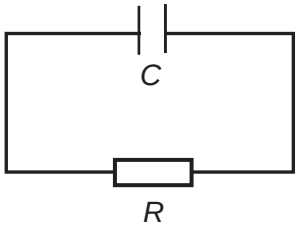

Fig. 6.4

Fig. 6.5 shows the variation with time *t* of the potential difference *V* across the resistor.

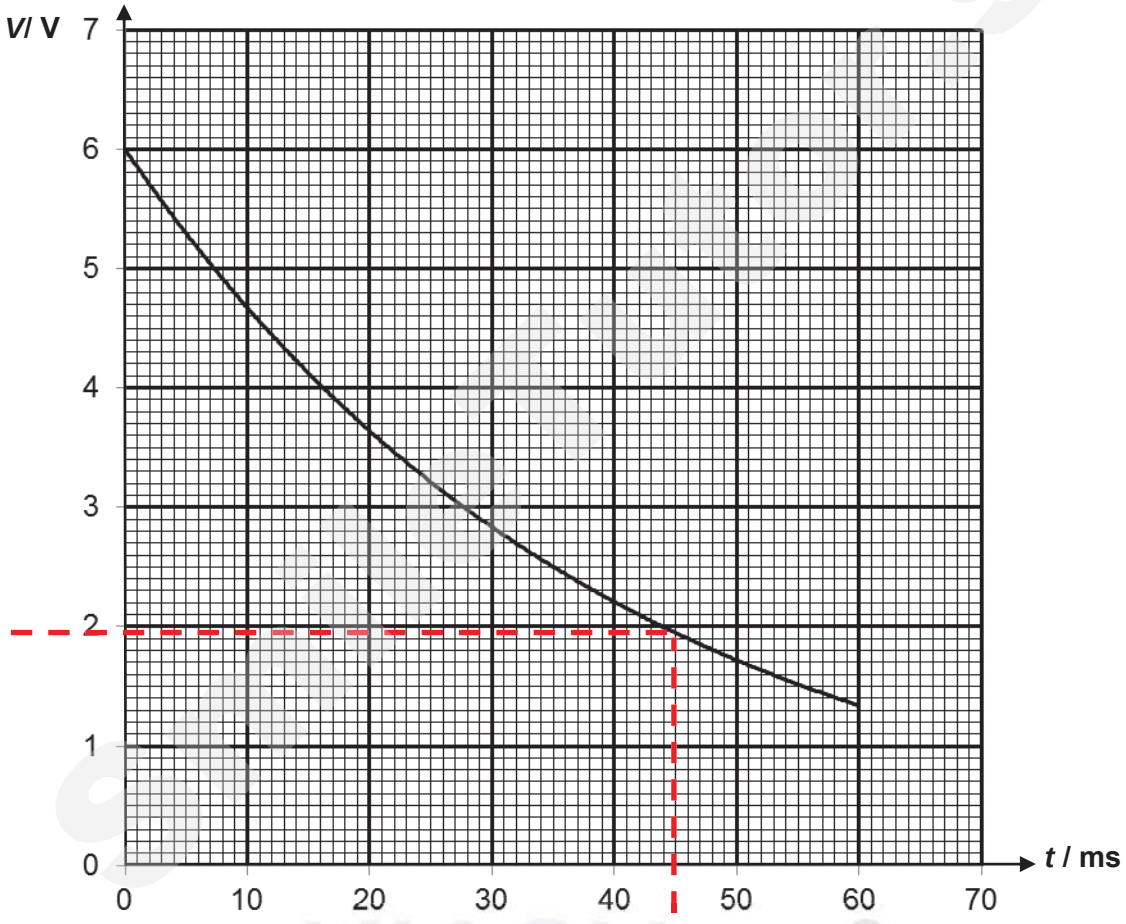

Fig. 6.5

(i) Using Fig. 6.3 and Fig. 6.5, determine the initial amount of charge stored.

From Fig 6.5, at t = 0, V = 6.00 V [M1]

From Fig 6.3, read off best fit line. At 6.00 V, Q = 28.00 μC [A1]

-1m overall for wrong d.p.

charge = ... μC [2]

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(ii) Hence, calculate the capacitance *C*.

Q = CV
C = Q/V
= 28.00 x 10^{-6} / 6.00 [M1]
= 4.67 x 10^{-6} C V^{-1} [A1]

capacitance = ... C V^{-1} [2]

(iii) Calculate the energy lost when the capacitor has been discharged for 45 ms.

At 45 ms, V = 1.95 V [M1]

Energy lost = ½ C (V_i^2 – V_f^2) [M1]
= ½ (4.67 x 10^{-6}) (6.00^2 – 1.95^2)
= 7.52 x 10^{-5} J [A1]

-1m overall for wrong d.p.

energy lost = ... J [3]

(d) The graph in Fig. 6.5 can be represented by the following equation, where V_o is the initial potential across the resistor *R*.

$$V = V_o e^{-t/RC}$$

State how the value of *RC* affects the rate of discharge of the capacitor.

A greater value of *RC* slows down the rate of discharge. ..... [1]

(e) Fig 6.6 shows an A.C. supply connected to resistor-capacitor (RC) circuit containing an ideal diode. Fig 6.7 shows the potential difference measured by the CRO.

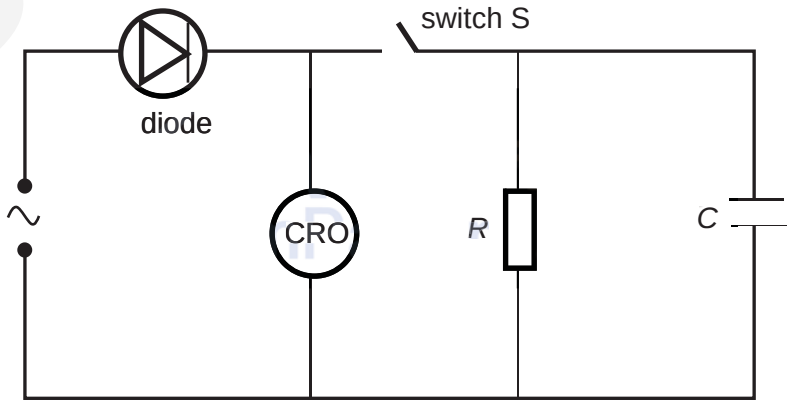

Fig. 6.6

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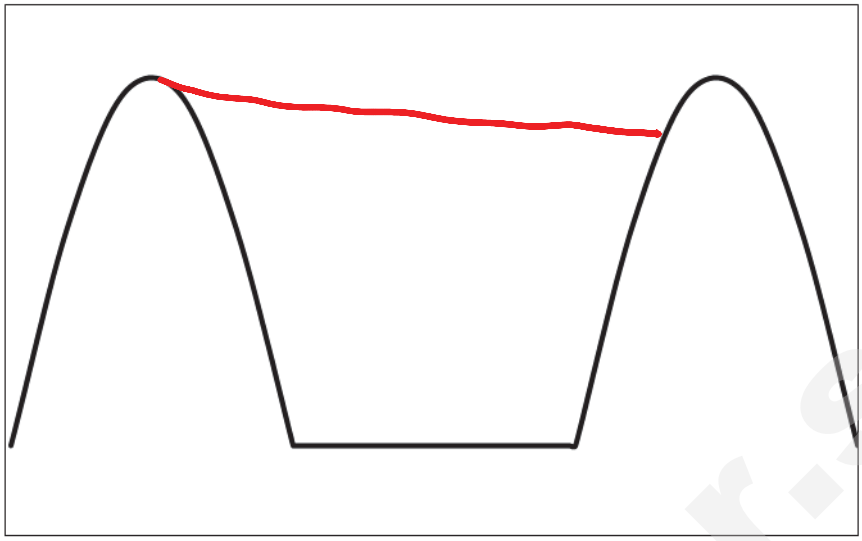

Fig. 6.7

Switch S is now closed. When the diode is in forward bias, current flows through both the resistor and the capacitor. When the diode is in reverse bias, the capacitor discharges through the resistor.

(i) Sketch on Fig. 6.7, the expected display on the CRO. [1]

(ii) State what the RC circuit does to the wave on the CRO.

Smoothen the ripples (of a half wave rectified signal). [1]

END OF PAPER

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READ THIS INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions in Section A, and **one** of the two questions in Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in bracket [ ] at the end of each question or part question.

For Examiners' Use	
Q1	/ 7
Q2	/ 13
Q3	/ 20
Q4	/ 20
Q5	/ 20
Q6	/ 20
Total marks	/ 80

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For Examiner's Use

DATA AND FORMULAE

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\frac{1}{36\pi} \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23}J K^{-1}
gravitational constant	G	=	6.67×10^{-11}N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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DATA AND FORMULAE

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anqv$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \cdots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/ voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A: Answer all questions

1 A uniform rod of weight 20 N is freely hinged to a wall at P as shown in Fig. 1.1. It is held horizontal by an elastic cord made of material X of force constant 10 N cm^{-1}, attached at Q at an angle of 15° to the rod.

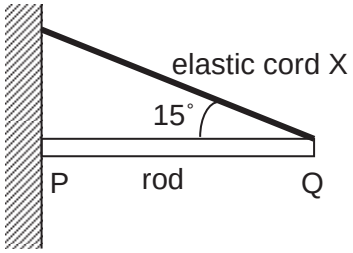

Fig. 1.1

(a) Show that the extension of the elastic cord X is 3.86 cm. [2]

Let L be the length of the rod and x be the extension of elastic cord.
Using Principle of Moments, taking moments about point X
Sum of clockwise moment = Sum of anticlockwise moment
Or
W (0.5 L) = (T sin 15°) L [B1]
20 (0.5 L) = (10x sin 15°) L [B1]
x = 3.86 cm

(b) Determine the magnitude of the resultant force acting at P.

Consider vertical forces
Taking upwards positive
T sin 15° + R_2 + (-W) = 0
38.6 sin 15° + R_2 + (-20) = 0 [M1]
R_2 = 10.0 N

Consider horizontal forces
Taking rightward positive
R_1 + (-T cos 15°) = 0
R_1 + (-38.6 cos 15°) = 0 [M1]
R_1 = 37.2 N

$R = \sqrt{R_1^2 + R_2^2} = \sqrt{10.0^2 + 37.2^2} = 38.5$ N [A1]

magnitude of resultant force at P = …… N [3]

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(c) The elastic cord X is now replaced by two other identical elastic cords of the same unstretched length as elastic cord X. These two elastic cords are connected in parallel. The rod PQ remains horizontal.
State and explain the value of the force constant of each of the new elastic cords.

Each elastic cord experiences half of the tension as that in elastic cord X. Since the extension of each cord is the same as that of elastic cord to keep rod PQ horizontal [M1], therefore the force constant of each of the new cord is 5 N cm^{-1}. [A1]

OR

Since the elastic cords are connected in parallel, their effective force constant is same as that of elastic cord X, and the effective force constant is the sum of the force constants of the two cords [M1]. The force constant of each of the new cord is 5 N cm^{-1}. [A1]

.....
.....
..[2]

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2 (a) State the *first law of thermodynamics*, indicating the directions of all energy changes.

.....
.....
.....

Increase in internal energy of a system is the sum of the heat supplied to (or absorbed by) the system, and work done on the system.
[1 mark for $\Delta U = Q + W$, 1 mark for indicating correct direction, ie increase in internal energy, supplied to and work done on]

[2]

(b) A heat pump contains a fixed mass of ideal gas undergoing a cycle of changes of pressure, volume and temperature as illustrated in Fig. 2.1.

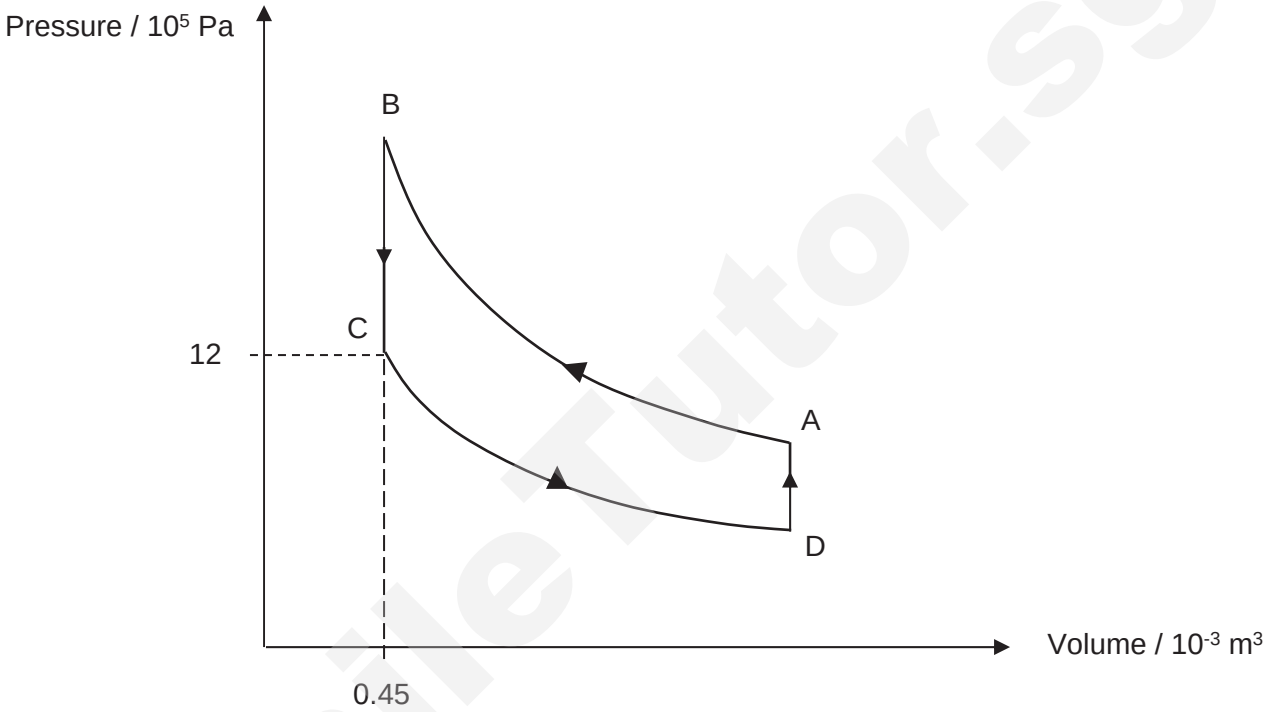

Fig. 2.1

The increase in internal energy which takes place during three of the changes are as shown in Fig. 2.2. It is also known that no heat is supplied in the changes A → B and C → D.

(i) Complete Fig. 2.2.

Change	Increase in internal energy / J	Heat supplied to gas / J	Work done on gas / J
A → B	720	0	720
B → C	-810	-810	0
C → D	- 360	0	-360
D → A	450	450	0

Fig 2.2

0.5 marks for each correct answer except for Q for A→B and C→D, combined 0.5 marks

[4]

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(ii) Given that the temperature at C is 360 K, calculate the number of molecules, N, in the heat pump.

PV = NkT
$(12 \times 10^5)(0.45 \times 10^{-3}) = N\ (1.38 \times 10^{-23})(360)$ [M1]
$N = 1.09 \times 10^{23}$ [A1]

number of molecules = ……[2]

(iii) Given that the total kinetic energy of the gas molecules, E_K is given as E_K = 3/2 NkT, using your answers in **(i)** and **(ii)**, determine the temperature at D.

Since this is an ideal gas, $\Delta U = \Delta E_K$.
Considering the process C to D,
$\Delta U = -360$, $\Delta E_K = 3/2 Nk\Delta T$,
Therefore, $-360 = 3/2 Nk\Delta T$ [M1]
$= 3/2\ (1.09 \times 10^{23})(1.38 \times 10^{-23})\ \Delta T$
$\Delta T = -160$K [M1]
Therefore, temp at D = 360 + (- 160)
= 200 K [A1].

OR

E_K at C = 3/2 NkT = 3/2 $(1.09 \times 10^{23})(1.38 \times 10^{-23})(360)$ = 810 J [M1]
E_K at D = 810 – 360 = 450 J [M1]
Using E_K = 3/2 NkT
$450 = 3/2\ (1.09 \times 10^{23})(1.38 \times 10^{-23})\ T_D$
T_D = 200 K [A1]

temperature = …… K [3]

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(iv) Given that the gas is Helium-4, calculate the root-mean-square speed of the Helium molecules at C.

½ m$\langle c^2 \rangle$ = 3/2kT
$\sqrt{\langle c^2 \rangle}$ = $\sqrt{3kT/m}$
= $\sqrt{}$ 3(1.38 x 10^{-23})(360)/(4x1.66x10^{-27}) [M1]
= 1,500 m s^{-1} [A1]

OR

pV = 1/3 Nm$\langle c^2 \rangle$
$\sqrt{\langle c^2 \rangle}$ = $\sqrt{}$ (3pV) / (Nm)
= $\sqrt{}$ 3(12 x 10^5)(0.45 x 10^{-3}) / (1.09 x 10^{23}))(4x1.66x10^{-27}) [M1]
= 1,500 m s^{-1} [A1]

OR

E_K at C = 3/2 NkT = 3/2 (1.09 x 10^{23})(1.38 x 10^{-23})(360) = 810 J

$$\frac{1}{2}Nm\langle c^2 \rangle = 810$$

$$c_{rms} = \sqrt{\frac{2(810)}{1.09\times10^{23}(4\times1.66\times10^{-27})}}$$ [M1]

$= 1500 \text{ m s}^{-1}$ [A1]

OR

$$\frac{1}{2}Nm\langle c^2 \rangle = \frac{3}{2}nRT$$

$c_{rms} = \sqrt{\frac{3RT}{M_r}}$ where M_r is molar mass

$$= \sqrt{\frac{3(8.31)(360)}{4\times10^{-3}}}$$ [M1]

$= 1500 \text{ m s}^{-1}$ [A1]

r.m.s speed = …… m s^{-1} [2]

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3 (a) A satellite is in a geostationary circular orbit of radius *r* about the Earth of mass *M*, and appears to remain above the same point on the Earth. The mass of the Earth may be assumed to be concentrated at its centre.

(i) State two features of a geostationary satellite of the Earth.

1. ……
……
2. ……

Any 2:
1. Period of orbit is 24 hours
2. Satellite lies on a plane containing the Earth's equator
3. Satellite rotates from west to east
4. Satellite's orbital radius is 42300 km

……[2]

(ii) Show that the period *T* of the orbit of the satellite is given by the expression

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where G is the gravitational constant. Explain your working.

Gravitational force provide the centripetal force [B1]
$GMm/r^2 = mr\omega^2$ [M1]
and since $\omega = 2\pi/T$ [M1]

Therefore, $T^2 = 4\pi^2r^3/GM$

[3]

(iii) The mass *M* of the Earth is 6.0×10^{24} kg. Determine the radius of the geostationary orbit.

Using $T^2 = 4\pi^2r^3/GM$
$(24 \times 3600)^2 = 4\pi^2r^3/ (6.67 \times 10^{-11} \times 6.0 \times 10^{24})$ [M1]
$r = 4.2 \times 10^7$ m [A1]

radius = …… m [2]

(b) The variation of the resultant gravitational potential due to the Earth and the Moon along a line XY joining the centres of the Earth and Moon is as shown in Fig. 3.1.

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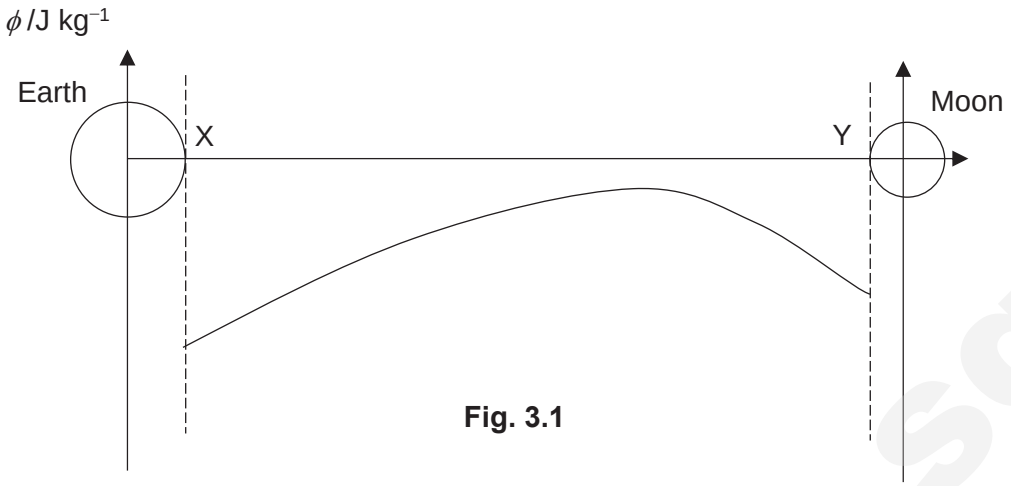

Fig. 3.1

(i) Given that the mass of the Moon is 7.3 x 10^{22} kg and the distance between the centres of the Earth and Moon is 380 000 km, show that the distance from the centre of the Earth along XY, where the net gravitational field strength is zero, is 342 000 km.

Let x be the distance in km.
Magnitude of Gravitational field strength due to Earth = magnitude of gravitational field strength due to Moon
$GM_E/x^2 = GM_M/(380{,}000 - x)^2$
$6.0 \times 10^{24} / x^2 = 7.3 \times 10^{22} / (380{,}000 - x)^2$ [M1]
x = 342,000 km

[1]

(ii) Hence, sketch the corresponding net gravitational field strength due to the Earth and the Moon in Fig. 3.2. [2]

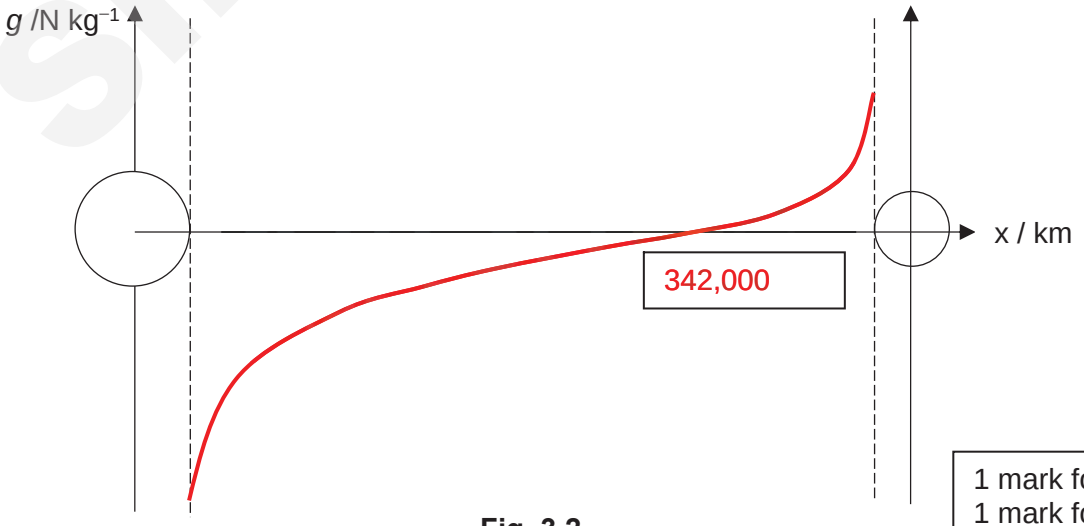

Fig. 3.2

1 mark for correct shape
1 mark for marking the x-intercept correctly

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(c) Two point charges A and B are separated by a distance of 8.0 cm in a vacuum, as illustrated in Fig. 3.3.

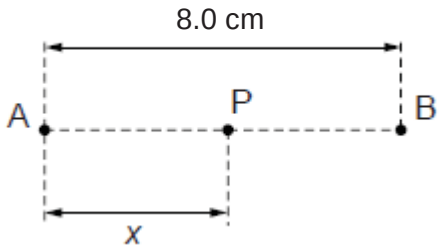

Fig. 3.3

Point P is at a distance *x* from A along AB. The variation of the resultant potential due to charge A and B is as shown in Fig. 3.4.

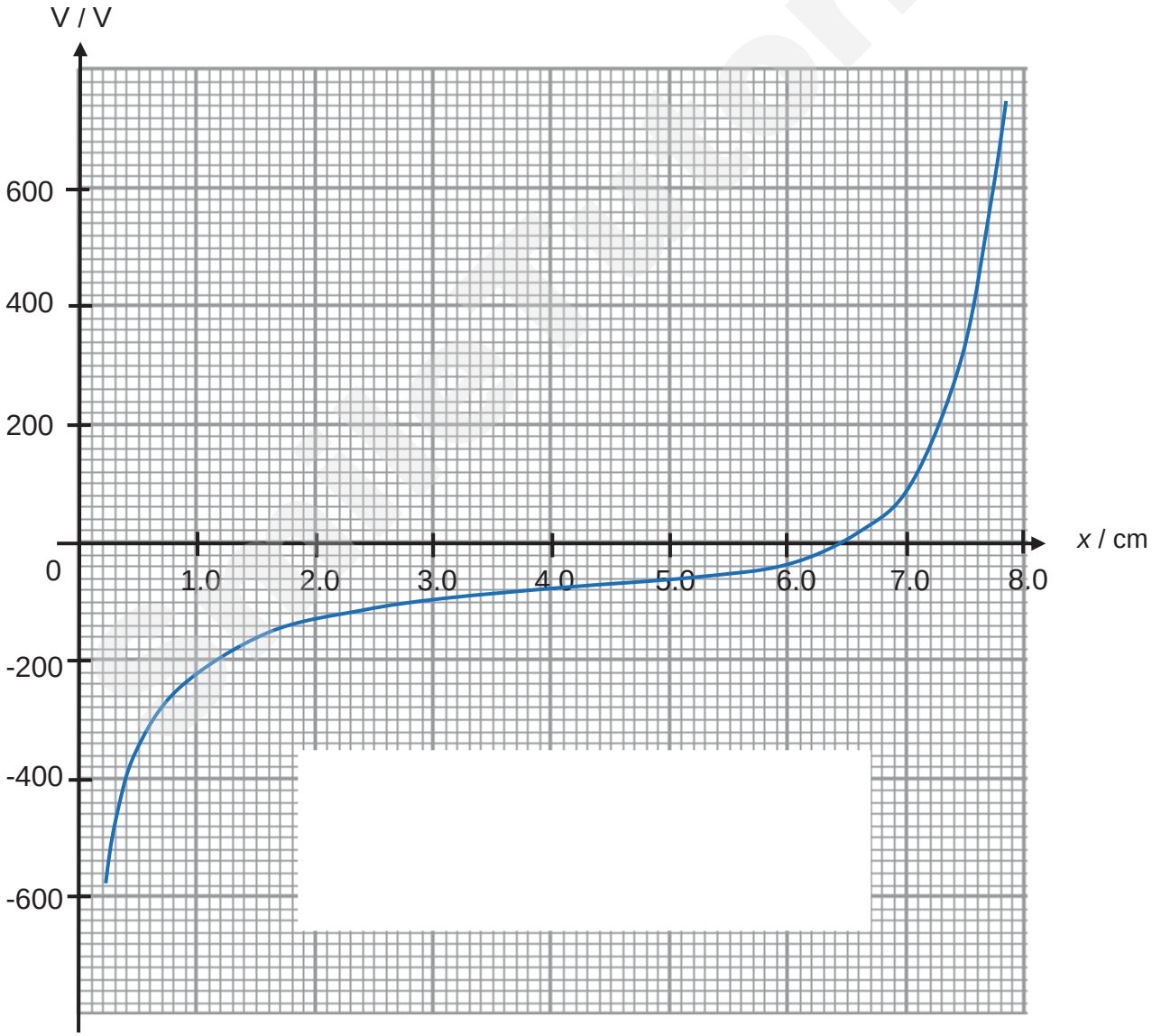

Fig. 3.4

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(i) State and explain whether the two charges are of the same sign.

The 2 charges are of different sign [A1] as the resultant electric potential varies from negative to positive [M1], or there is a point where the net electric potential is 0 [M1].

(ii) Calculate the ratio of the numerical value of $\frac{\text{Charge of } A}{\text{Charge of } B}$

At x = 6.50 cm , $V_A + V_B = 0$
Therefore,
$|Q_A/4\pi\varepsilon_o(6.50)| = |Q_B/4\pi\varepsilon_o(8.00-6.50)|$ [M1]
Therefore $|Q_A/Q_B| = 4.33$ [A1]

ratio = ……[2]

(iii) State and explain the direction of the electric field at the point P, where x = 2.0 cm.

Direction is towards the charge A (or to the left) [A1]
Reason :
Electric field strength points towards decreasing potential [M1], **or** since charge A is a negative charge and charge B is a positive charge, the electric field strengths due to A and B are both towards the left at point P [M1] **or**
Since E = -dV/dx, since dV/dx is positive, E is negative [M1]

(iv) Sketch the variation of the electric field strength with x in Fig. 3.5. Label where appropriate.



Fig. 3.5

1 mark for correct shape
1 mark for marking where the turning point is
(accept from 4.5 to 5.3 cm)

[2]

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(v) When a -2.0 nC charge is moved from x = 3.0 cm to 6.0 cm, calculate the change in kinetic energy of the -2.0 nC charge.

Change in EPE
$= q\Delta V$
$= -2.0 \times 10^{-9}$ (-40-(-100)) [M1]
$= -1.2 \times 10^{-7}$ J
Since change in EPE is a loss, hence change in KE is a gain of 1.2×10^{-7} J [A1].

change in kinetic energy = …… J [2]

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4 (a) By reference to the photoelectric effect, explain

(i) what is meant by *work function*,

Minimum (photon) energy that is required to remove an electron from the surface

(ii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energies up to a maximum value.

KE is maximum when electrons at the surface are ejected [B1]
KE can be lower than the maximum energy because energy is required to bring electron deeper in the metal to the surface or electron loses energy when it makes its way to the surface [B1]

(iii) In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface, and the maximum kinetic energy E_{max} of $1/\lambda$ as shown in Fig. 4.1.

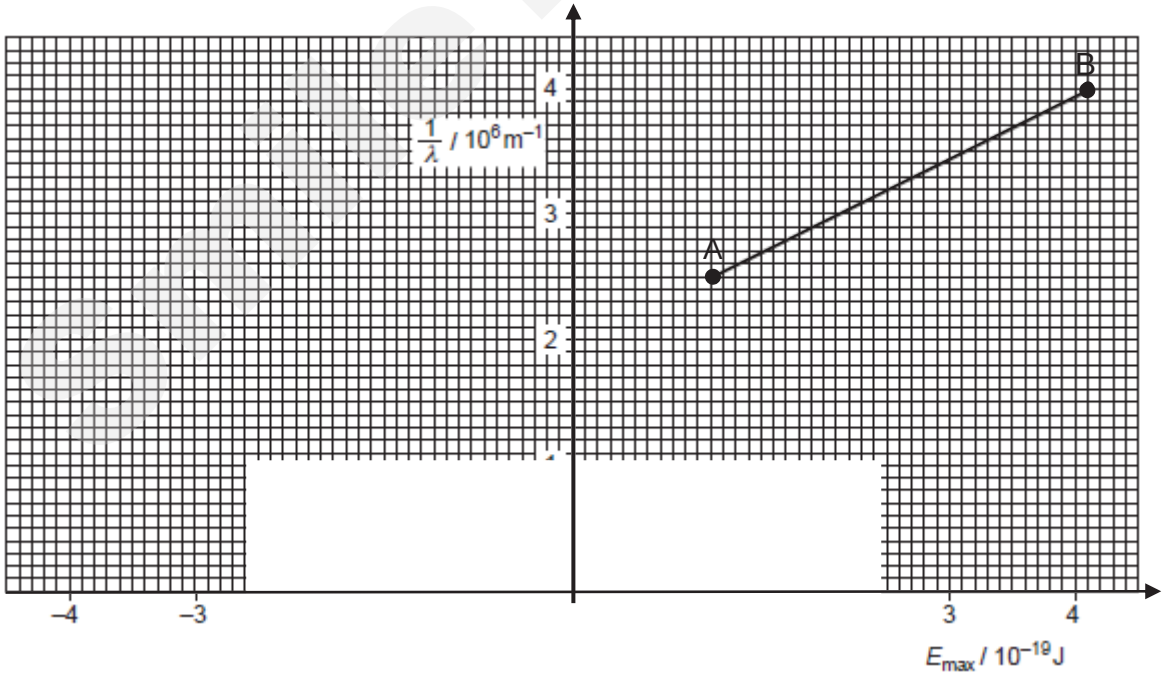

Fig. 4.1

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1. Without using the value of the Planck constant, determine the work function of the metal surface.

hc/λ = Φ + E_{max}
1/λ = Φ/hc + E_{max}/hc
At x-intercept, Φ = - E_{max}
Either extend line to intersect on x-axis [M1]
Or form eqn of straight line to solve [M1]
Φ = 4.0 x 10^{-19} J (allow ± 0.2 x 10^{-19} J)[A1]

work function = …… J [2]

2. Using points A and B, determine the Planck constant.

Gradient of line = 1/hc [M1]
Correct coordinates of points to half a square and correct calculation of gradient [M1]
Correct h = 6.6 to 6.9 x 10^{-34} J s [A1]

Planck constant = …….. J s [3]

(b) Fig. 4.2 shows how x-rays are produced inside an x-ray tube. The electrons emitted at the filament are accelerated from rest using an accelerating voltage to hit a target of heavy metal at the anode and produce x-rays as a result.

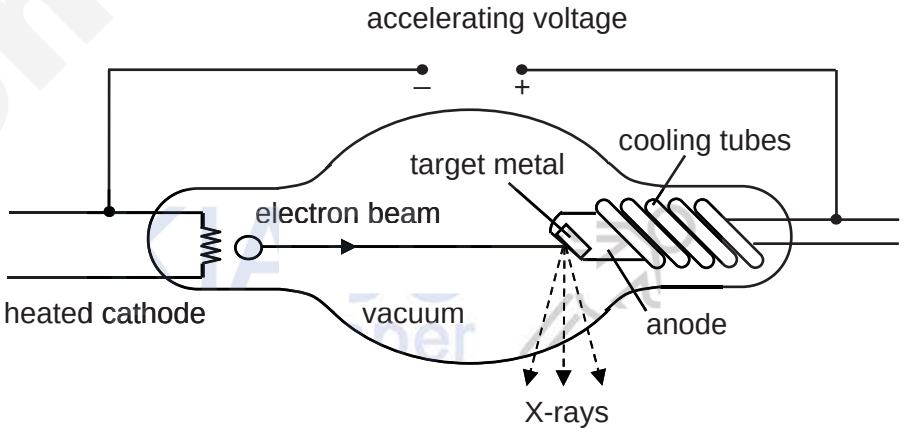

Fig 4.2

A graph of relative intensity against wavelength of the emitted radiation is as shown in Fig. 4.3.

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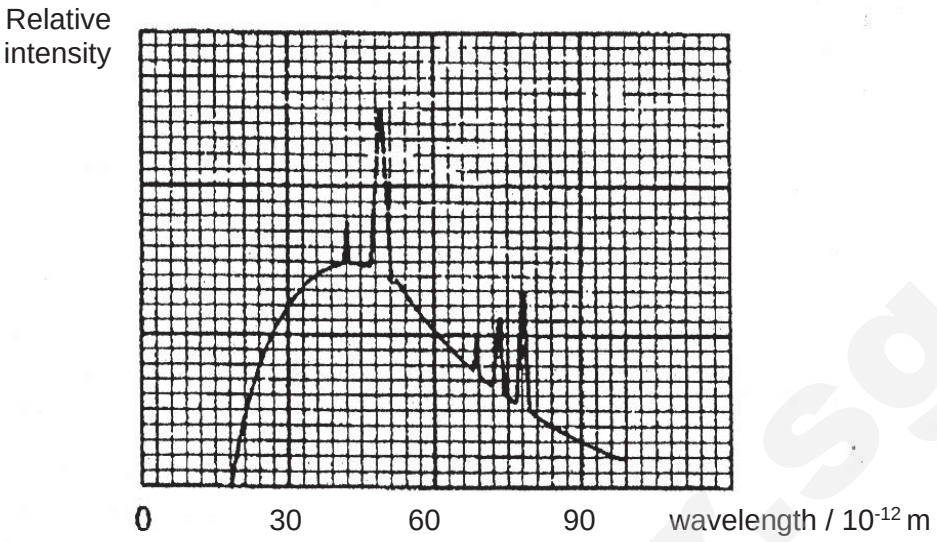

Fig. 4.3

(i) State and explain what must be done to the accelerating voltage if the minimum wavelength of the x-rays emitted is to be doubled.

The maximum energy of the X-ray photon (= hc/λ_{min}) emitted is equal to the kinetic energy of electrons upon hitting target, which is in turn equal to the loss in electric potential energy of the electrons as they are accelerated [M1].

Hence for λ_{min} to be doubled, the accelerating voltage must be halved [A1].

[2]

(ii) Determine the accelerating voltage used to produce the minimum wavelength as shown in Fig. 4.3.

Solution

Max energy of x-ray photons = KE gain of electron upon acceleration = EPE loss of electron [B0]

$hc/\lambda_{min} = eV_a$ [M1]

$V_a = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / (18.0 \times 10^{-12} \times 1.6 \times 10^{-19})$

$= 69.1$ kV [A1]

Accelerating voltage = …….. kV [2]

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(c) Electrons, accelerated through a potential difference, are incident on a very thin carbon film, with speed v as shown in Fig. 4.4.

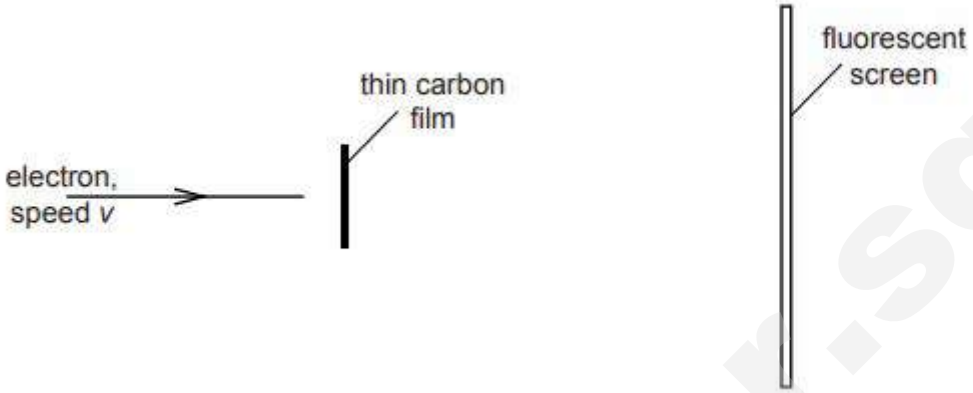

Fig. 4.4

The emergent electrons are incident on a fluorescent screen. A series of concentric rings is observed on the screen.

(i) State and explain what the observed rings suggest about the nature of the electrons.

The observed rings suggest that the electrons behave like waves (or provide evidence for the wave nature of particles) [M1]

as when light passes through suitable film, diffraction occurs and similar pattern observed [A1]
Or
concentric circles are evident of diffraction and diffraction is a wave property [A1]

[2]

(ii) The stream of electrons is now replaced by a stream of alpha particles arriving at the thin film with the same speed v. State and explain the effect, if any, on the rings observed on the screen.

Mass is larger, hence momentum increases
$\lambda = h/p$ so λ decreases [M1]
Hence radii decrease [A1] or if wavelength is no longer comparable to the inter-atomic spacing, there will be no diffraction and hence no concentric rings will be observed.

Or
Mass is larger, hence kinetic energy increases [M1]
$\lambda = h/\sqrt{(2mKE)}$, so λ decreases [M1]
Hence radii decrease [A1] or if wavelength is no longer comparable to the inter-atomic spacing, there will be no diffraction and hence no concentric rings will be observed.

[3]

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(iii) A proton and an alpha particle are each accelerated from rest through the same potential difference. Determine the ratio

$$\frac{\text{de Broglie wavelength of the proton}}{\text{de Broglie wavelength of the alpha particle}}$$

Since proton and alpha particle are accelerated from rest through the same potential difference and the charge of the alpha particle is double that of the proton, the ratio of their kinetic energy, KE is:

$\frac{E_p}{E_\alpha} = \frac{eV}{2eV}$ = ½ [M1]

Since $E = p^2/2m$ or $p = \sqrt{(2m\ KE)}$ and $\lambda \alpha 1/p$,
Therefore, $\lambda \alpha 1\sqrt{(m\ KE)}$ [M1]

Therefore ratio = $\sqrt{\frac{m_\alpha}{m_p}} \times \sqrt{\frac{E_\alpha}{E_p}}$

= $\sqrt{4} \times \sqrt{2}$

= 2.83 [A1]

Or

Gain in KE = $\frac{p^2}{2m}$

Loss in EPE = qV

Since gain in KE = loss in EPE

$\frac{p^2}{2m} = qV$

$p = \sqrt{2mqV}$

Since $\lambda \alpha 1/p$ and V is constant, therefore ratio = #

$\sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}}$

$= \sqrt{4 \times 2}$

= 2.83

..... [3]

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Section B: Answer ONE out of TWO questions.

5 (a) The headlights of a car are switched on. The distance along the copper connecting wires between the car battery and one of the headlights is 1.5 m.

(i) The current in the wire is 3.0 A, the cross-sectional area of the wire is 3.0×10^{-7} m^2, and the number density of electrons in copper is 8.5×10^{28} m^{-3}.
Determine the average time that an individual electron will take to drift from the battery to the headlight.

$$v = \frac{I}{nAe} = \frac{3}{(8.5\times10^{28})(3\times10^{-7})(1.6\times10^{-19})} = 7.3529\times10^{-4} \text{ m s}^{-1} \quad [M1]$$

Therefore time taken,

$$t = \frac{\text{distance}}{\text{speed}} = \frac{1.5}{7.3529\times10^{-4}} = 2040 \text{ s} \quad [A1]$$

time taken = …… s [2]

(ii) Using your answer in **(i)**, comment on how the light of the headlamp comes on almost immediately when switched on.

Although the time taken for the electron to travel from the car battery to headlamp is very long (or the drift velocity is very small), ALL the electrons in the entire complete circuit have a net movement in a single direction [B1] from lower to higher potential. Thus light comes on almost instantaneously.

…… [1]

(b) An electric heater consists of three similar heating elements A, B, C, connected as shown in Fig. 5.1.

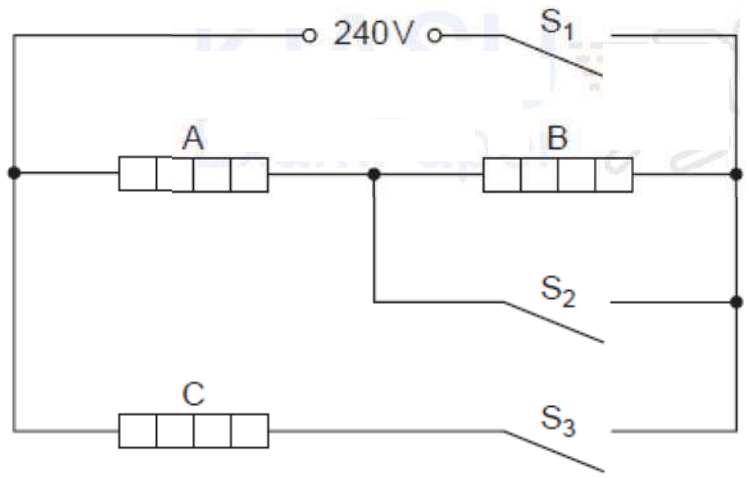

Fig. 5.1

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Each heating element is rated as 1.5kW, 240V and may be assumed to have constant resistance.
The circuit is connected to a 240 V supply.

(i) Calculate the resistance of one heating element.

$$P = \frac{V^2}{R}$$
$$R = \frac{V^2}{P} = \frac{240^2}{1500} = 38.4\ \Omega$$

[M1 for formula, A1 for substitution and answer]

resistance = ……..Ω [2]

(ii) The switches S_1, S_2 and S_3 may be either open or closed.

1. When S1, S2 and S3 are all closed, state the total power dissipation of the heater.

B is bypassed and current flows through A and C. P.d. across A and C is 240V.
So A and C dissipates 1.5 kW each, and collectively 3.0 kW.

total power dissipation = …….. kW [1]

2. When S1 is closed, S2 is open, and S3 is open, determine the total power dissipation of the heater. [2]

Current flows through A and B, but not C. P.d. across A and B is 120V each. Since $P=V^2/R$, power is proportional to V^2 (for constant R).

$$\frac{P_{120}}{P_{240}} = \frac{V_{120}^2}{V_{240}^2}$$
$$\Rightarrow P_{120} = P_{240}\frac{V_{120}^2}{V_{240}^2} = 1.5\frac{120^2}{240^2} = 0.375\ \text{kW} \quad [\text{M1}]$$
$$\Rightarrow P_{total} = 0.375 + 0.375 = 0.750\ \text{kW} \quad [\text{A1}]$$

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3. Hence, determine the total power dissipation of the heater when S1 is closed, S2 is open, and S3 is closed.

Current flows through A, B and C. P.d. across A and B is 120V each, and as found in part (2) previously the power dissipated in A and B collectively is 0.75 kW.
P.d. across C is 240V, so power dissipated in C is 1.5kW.
Thus, all together, the total power dissipated in A, B and C
= 0.75 + 1.5 [M1]
= 2.25 kW [A1]

total power dissipation = …….. kW [2]

(c) A circuit used to measure the power transfer from a battery is shown in Fig. 5.2. The battery has an electromotive force (e.m.f.) *E* and an internal resistance *r*. The power is transferred to a variable resistor of resistance *R*, when the potential difference (p.d.) across it is *V,* and the current through it is *I*.

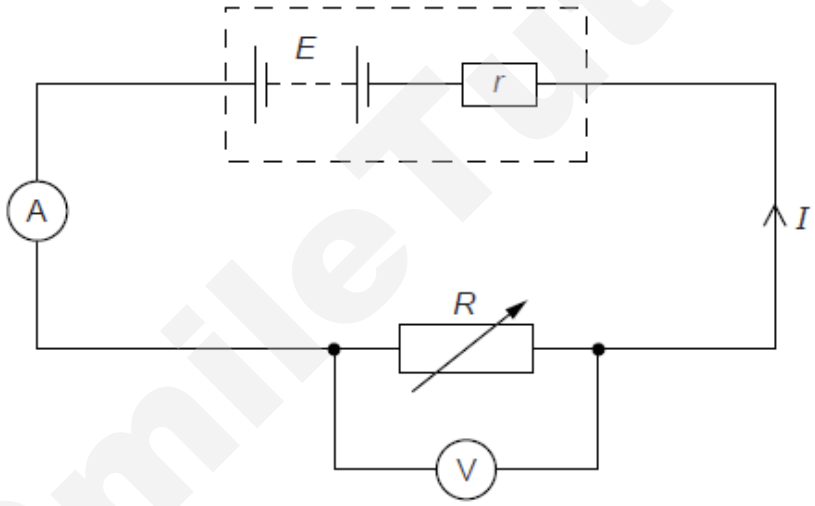

Fig. 5.2

(i) By reference to the circuit shown in Fig. 5.2, distinguish between the definitions of e.m.f. and p.d.

The electromotive force of a source is the electrical energy converted from other forms of energy per unit charge delivered round a complete circuit. [B1]

The potential difference between two points in a circuit is the amount of energy converted from electrical to other forms of energy per unit charge passing from one point to the other. [B1]

-1m if no "per unit charge" [2]

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(ii) The variation with current *I* of the p.d. *V* across *R* is shown in Fig. 5.3.

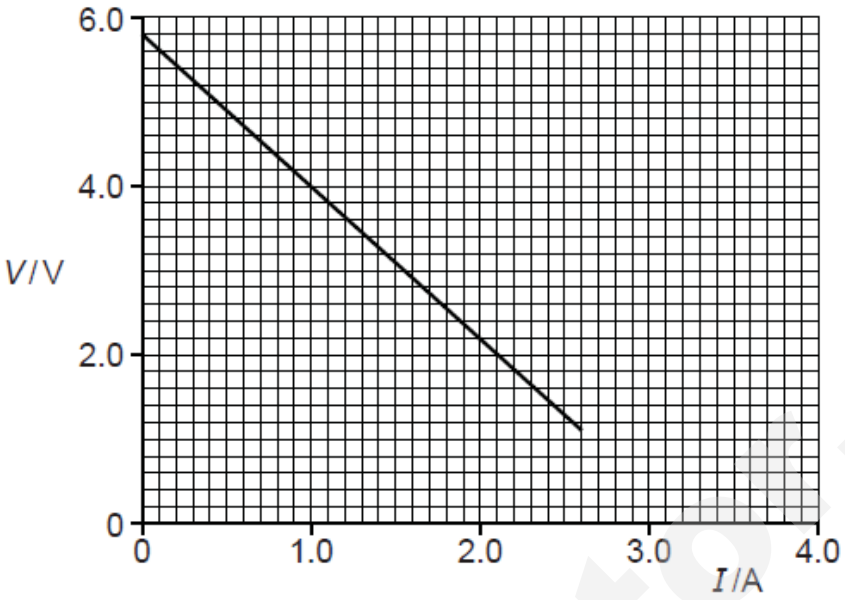

Fig. 5.3

Use Fig. 5.3 to determine

1. the e.m.f. *E*,

E = *IR* + *Ir*
IR = *E* – *Ir*
V = – *rI* + *E* *(where gradient is –r and y-intercept E)*

E = 5.8 V [B1] *(-1m overall if not in 1 d.p.)*

..V [1]

2. the internal resistance *r*.

Evidence of gradient calculation or calculation with values from graph
e.g. 4.0 = –r(1.00) + 5.8 [M1]
r = 1.8 Ω [A1]
OR
r = - gradient =| (5.8 – 2.2) / (0.00 – 2.00) | [M1]
= 1.8 Ω [A1]

(-1m overall if V not in 1 d.p. or I not in 2 d.p.)

r = ……Ω [2]

(iii) **1.** Using data from Fig. 5.3, show that the power transferred to *R* for a current of 1.6 A is 4.64 W. [1]

P = *VI*
= 2.9 x 1.6 [M1]
= 4.64 W [A1]

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2. Use your answers from **(ii)1** and **(iii)1** to calculate the efficiency of the battery for a current of 1.6 A.

power from battery = 1.6 x 5.8 = 9.28 W [M1]
efficiency = (4.64 / 9.28) x 100 = 50 % [A1]

efficiency = ……..% [2]

(iv) The variable resistor *R* in Fig. 5.2 is replaced by a few identical lamps connected in parallel. A student claims that as the number of lamps connected in parallel is increased, the lamps become dimmer. Comment on the student's claim.

With more lamps connected in parallel, the effective resistance across the lamps is lower than before. [M0]

Hence, the ratio of this effective resistance to the internal resistance falls, resulting in a smaller potential difference across the lamps. [M1]

The power dissipated by them will be lower (assuming the individual resistances of the lights remain the same). Thus, they become less bright. [A1]
So, the student's claim is valid. [A0]

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6 **(a)** A composite block of mass 10 kg, made of woods of different densities ρ_1 and ρ_2, floats in still water of density ρ_w, as shown in Fig. 6.1. Each portion of wood is of height x and of a base with cross-sectional area A.

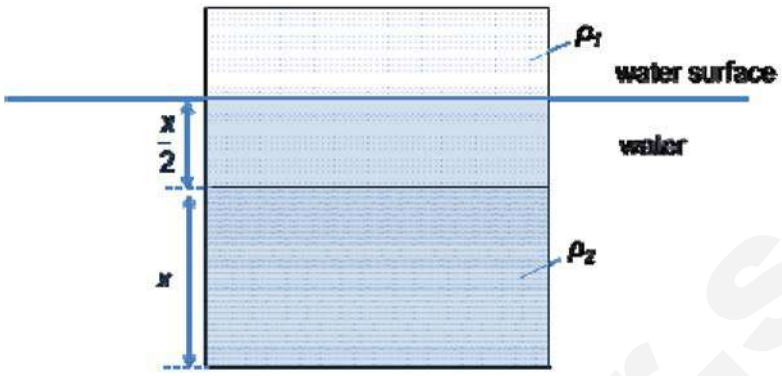

Fig. 6.1

(i) The block is pushed down by a distance l into the water without totally submerging it, and is then released.
It can be shown that the acceleration a of the block is given by

$$a = -\frac{\rho_w g}{(\rho_1 + \rho_2)x} l$$

Explain why the expression leads to the conclusion that the block bobs up and down in simple harmonic motion.

The negative sign shows that the **acceleration** (upwards) **is in the opposite direction to the displacement of the block** (downwards) [B1]
Since the three densities, x and g are constant, it can be seen that the **acceleration is directly proportional to the displacement**. [B1]
Therefore, the block moves in simple harmonic motion.

……[2]

(ii) The depth h of the block is measured from below the water surface to the base of the block as shown in Fig. 6.2.

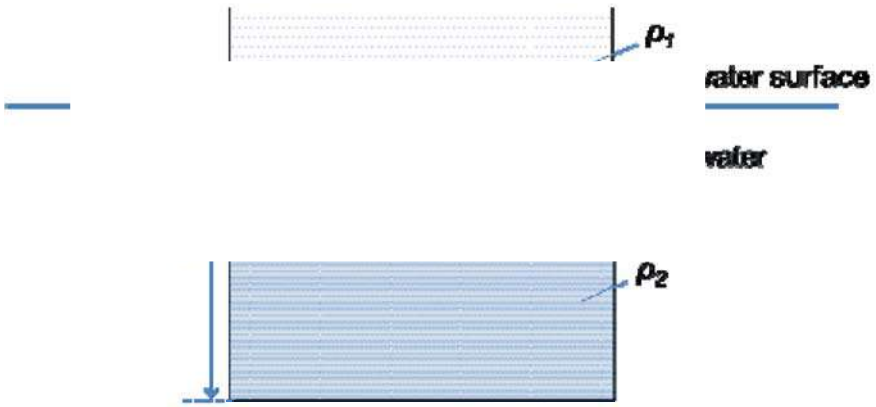

Fig. 6.2

Fig. 6.3 shows the variation with time t of the depth h of the base of the block below the surface.

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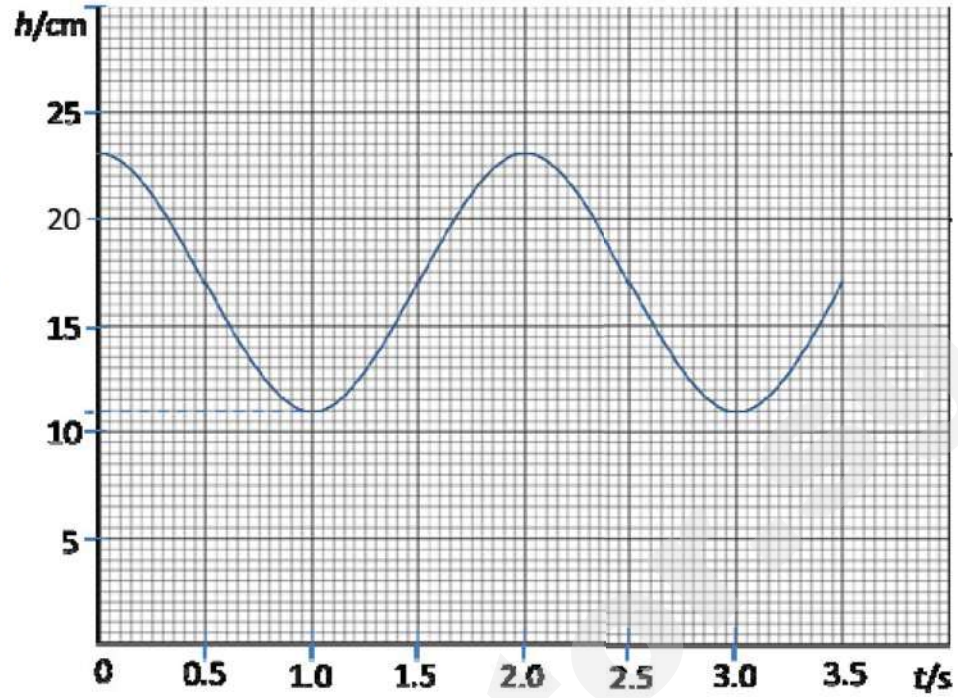

Fig. 6.3

1. Determine the amplitude of the oscillation of the block.

From the graph, maximum displacement = 23.00 cm
minimum displacement = 11.00 cm
amplitude = 0.5 (23.00 – 11.00)
= 6.00 cm = 0.0600 m [A1]

amplitude = …… m [1]

2. Determine the angular frequency of the oscillation.

From graph,
T = 2.000 s [M1]

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2.000} = 3.14 rads^{-1}$$ [A1]

angular frequency = …… rad s^{-1} [2]

3. Hence, show that the energy of the oscillation is 0.177J. [1]

Energy of Oscillation = Maximum KE

$$= \frac{1}{2} m\omega^2 x_0^2 = \frac{1}{2}(10)(3.14)^2(0.06)^2 = 0.177 J$$ [B1]

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(b) **(i)** State Faraday's law of electromagnetic induction.

The *magnitude* of the induced e.m.f. in a coil [B1] is directly proportional to the rate of change of the magnetic flux linking the coil / rate of cutting of magnetic flux [B1].

……[2]

(ii) A coil with 800 turns is placed in a uniform horizontal magnetic field of flux density 5.0×10^{-2} T. The area of the coil perpendicular to the field is 2.5×10^{-2} m^2, as shown in Fig. 6.4.

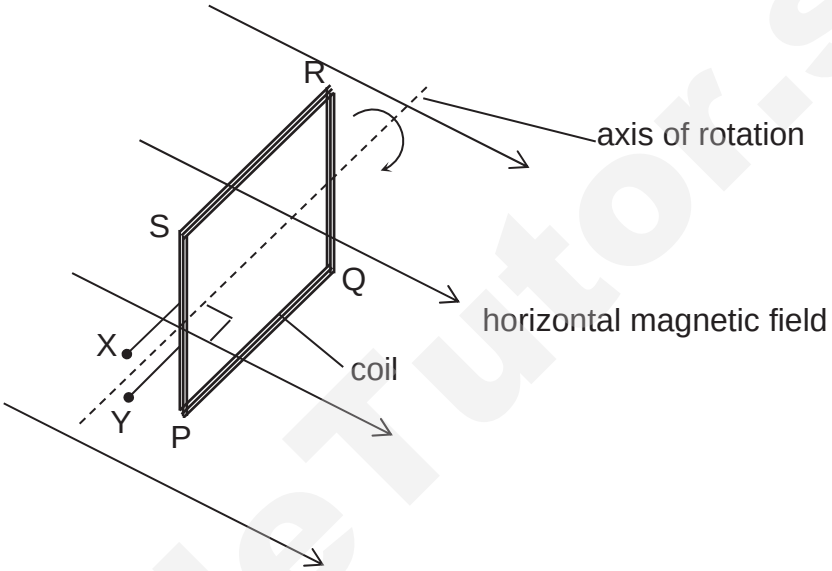

Fig. 6.4

1. Explain why an e.m.f. is induced in the coil.

The angle between the magnetic field and the plane of the coil (or the magnetic flux density perpendicular to the area of the coil, or the area of the coil perpendicular to the magnetic flux density) changes, OR the coil cuts the magnetic field lines. [B1]
Hence, there is a change in the magnetic flux linking the coil, causing an emf to be induced by Faraday's Law [B1].

2. Determine the magnetic flux linkage of the coil.

Φ = NBA [B1] = 800 x 5.0 x 10^{-2} x 2.5 x 10^{-2} = 1.0 Wb [B1]

magnetic flux linkage = …… Wb-turns [2]

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(c) The coil in **(b)** is rotated around the axis shown in Fig. 6.4. The flux linkage Φ of the coil varies with time t as shown in Fig. 6.5.

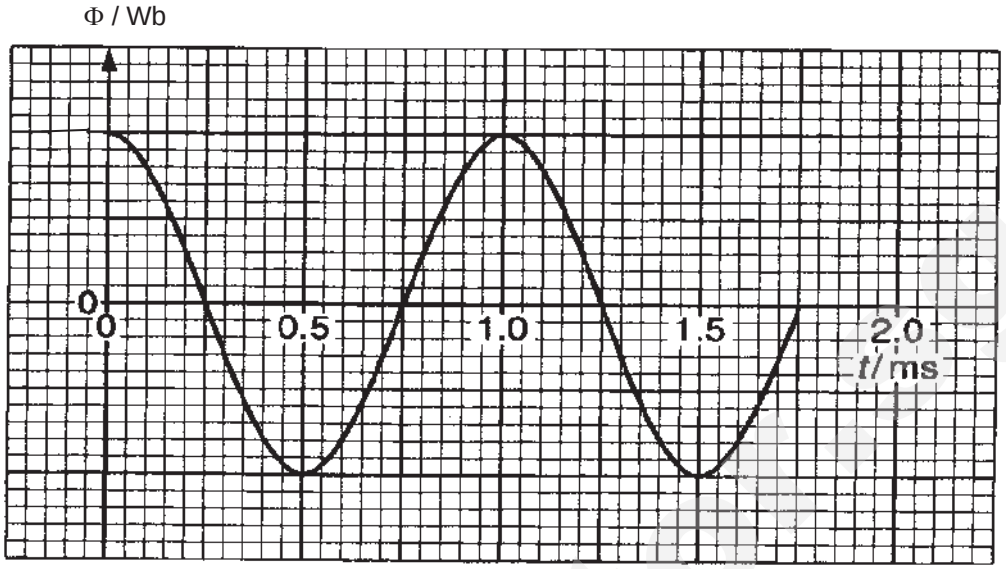

Fig. 6.5

(i) Derive the equation for the induced e.m.f. *E* of the coil, where *N* is the number of turns in the coil, *B* is the magnetic flux density, *A* is the area of coil, and ω is the angular frequency of the change in magnetic flux linkage. [2]

E.m.f. is given by

$$E = -\frac{d\Phi}{dt}$$

$$E = -\frac{d}{dt}\left(NBA\cos\omega t\right)$$ [M1 for expression for MFL, A1 for differentiation]

$$E = NBA\omega\sin\omega t$$

(ii) Sketch on Fig. 6.6 the variation with time of the e.m.f. across XY. Label the maximum value of the e.m.f. [2]

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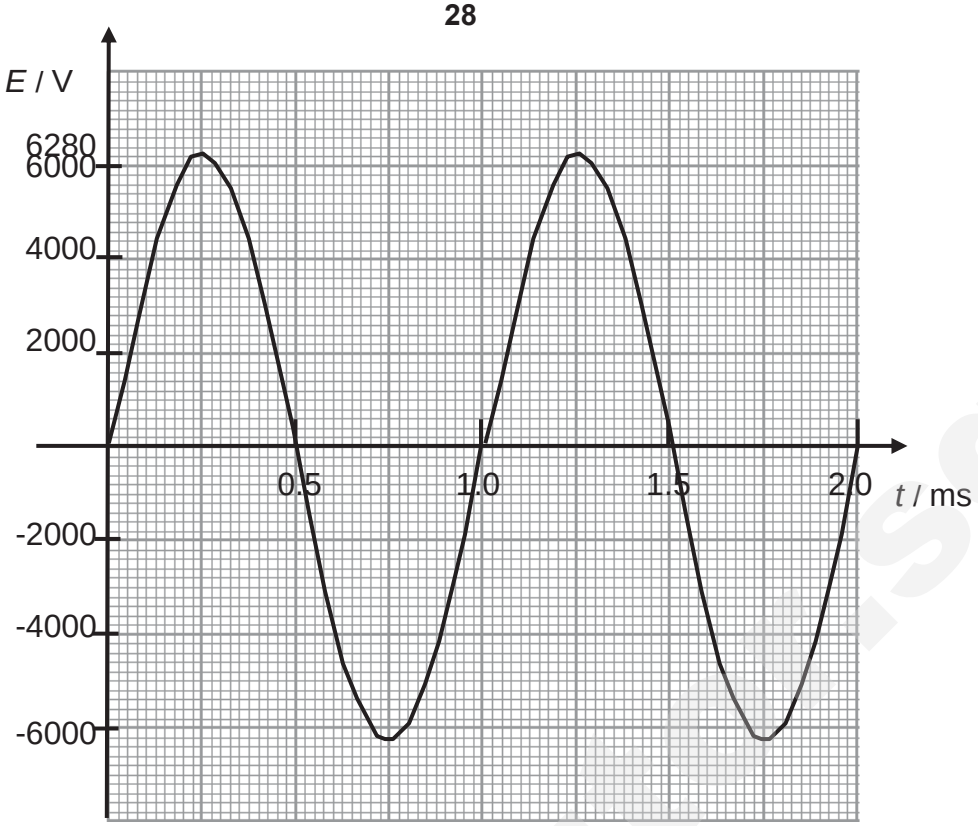

Fig. 6.6

[B1] for sine wave with same period
[B1] for labelling max e.m.f. as 6280 V (BOD wrong scale).

(d) A resistor of resistance 5000 Ω is now connected across XY.

(i) Determine the mean power dissipated in the resistor.

Mean power = $\frac{\left(\frac{V_o}{\sqrt{2}}\right)^2}{R} = \frac{\left(\frac{6280}{\sqrt{2}}\right)^2}{5000} = 3.94kW$ [B1] for formula and substitution. [B1] for answer

mean power = …… kW [2]

(ii) Use energy conservation to explain why the oscillations of the coil are damped.

Induced current flowing through resistor produces heating. [B1]
Thermal energy results in loss of mechanical/kinetic energy of oscillations. [B1]

……

……[2]

END OF PAPER

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General Certificate of Education Advanced Level
Higher 2

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PHYSICS 9749 / 04

Preliminary Examination **29 August 2017**
Paper 4 Practical **2 hour 30 minutes**

Candidates to answer all questions in the Question Booklet.

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or do not use appropriate units.

Give details of the practical shift and laboratory in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 14
2	/ 9
3	/ 20
4	/ 12
Total	/ 55

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1 This investigation considers the angles formed by the threads in a pulley system when it is in equilibrium.

(a) In this set-up, there are two threads – a long thread AB and a short thread CD, as shown in Fig.1.1. Two pulleys P and Q are identical.

Tie end A to the 100 g mass.

Pass the thread AB through pulleys P and Q.

Tie end B to the 50 g mass.

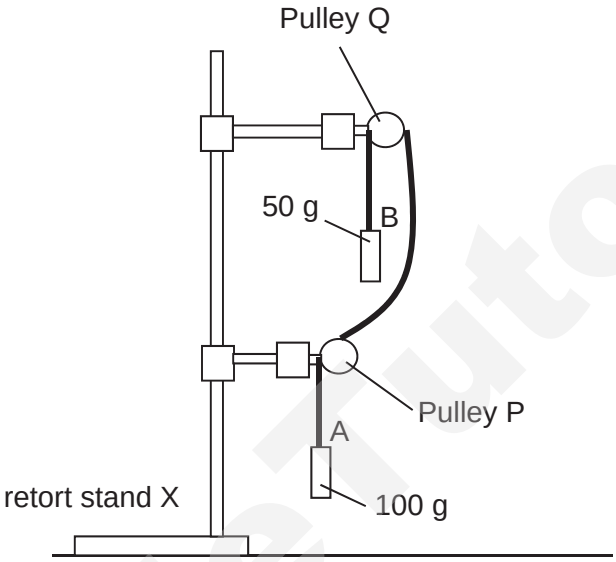

Fig.1.1

(b) Tie thread CD as shown in Fig.1.2. **Thread CD must be kept horizontal** throughout the whole experiment.

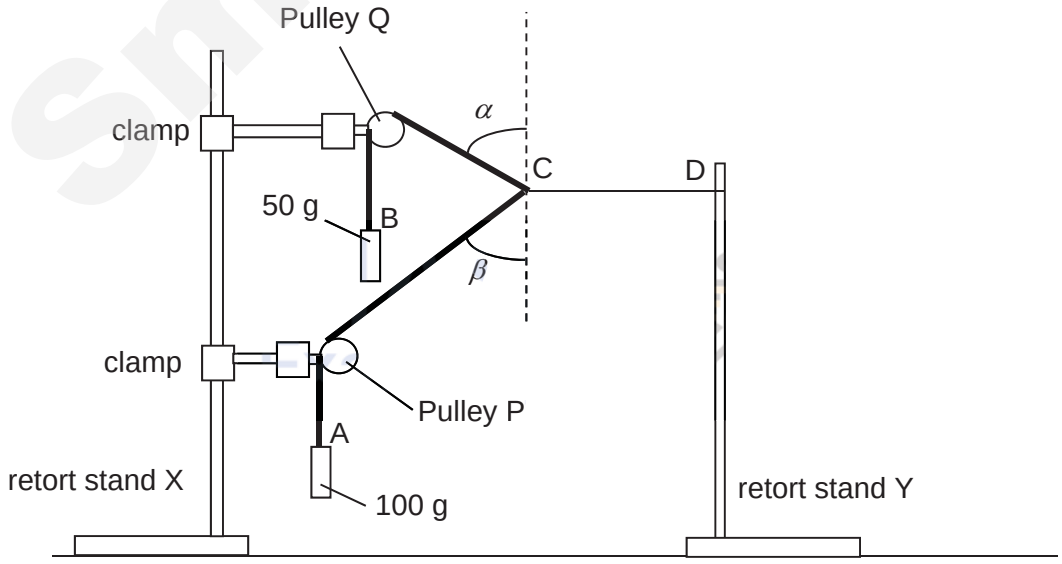

Fig.1.2

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(c) Measure the angles α and β.

Value of α and β to the correct precision with unit
Unit: ° (zero d.p.)
$\alpha < \beta$
α and β are less than 90°

α = ……

β = …… [1]

(d) Estimate the percentage uncertainty in α.

$\Delta\alpha = 2°$ (accept 2° to 4°)

$$\frac{\Delta\alpha}{\alpha} \times 100\% = \frac{2}{40} \times 100\% = 5\%$$

[Accept $\Delta\alpha = 1+1$ or 2×1. Ecf α for incorrect d.p. in (c)]

n α = …… [1]

(e) State one significant source of error that may have affected the accuracy of the readings of angles α and β.

1. Friction at the axle of pulleys / friction between thread and pulley.
2. Difficult to ensure that CD is horizontal.
3. Difficult to measure angles α and β due to absence of plumbline / reference line.
4. Difficult to measure the angle θ accurately because it is difficult to hold the protractor still and in position as the hands may be unsteady / because the protractor touches the threads.

……

……

……[1]

(e error identified in **(e).** You may suggest the use of other apparatus or a different procedure.

1. Lubricate the (axle of) the pulley.
2. Use spirit level metre / Use any horizontal reference in the lab / Use set squares to ensure CD is perpendicular to the retort stand.
3. Set up a plumbline / Clamp a ruler perpendicular to CD with another retort stand / Use set squares (and clamp the protractor using another retort stand).
4. Clamp the protractor using a retort stand instead, to measure the θ.

[Accept diagram to illustrate the idea]

……

……

….[1]

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(g) It is suggested that cos α is directly proportional to cos β. Move the retort stand Y to the right and adjust thread CD so that it is horizontal. Obtain one more set of values of α and β to investigate this suggestion. State and explain whether you agree with this suggestion.

Present your measurements and calculated results clearly. Plotting of graph is not required.

α / °	β_1 / °	β_2 / °	cos (α / °)	cos (β / °)	$k = \frac{\cos(\alpha / °)}{\cos(\beta / °)}$
40	70	72	0.76	0.33	2.3
55	73	74	0.57	0.28	2.0

[Accuracy of cos α and cos β: 1 mark.]

[S.f. of cos α and cos β: 1 mark.]

[Accuracy of constant of proportionality *k*: 1 mark]

[S.f. of constant of proportionality *k*: 1 mark]

[Calculation of % difference in values of *k* (1 or 2 s.f.): 1 mark]

[Draw conclusion based on stated criterion, e.g. not obeyed because more than 20% difference in values of *k*: 1 mark]

If $|k_1 - k_2|$ / smaller of k × 100% < 20%, then the suggestion that cos α is directly proportional to cos β is valid. [6]

(h) Let the tensions in CA, CB and CD be T_1, T_2, and T_3 respectively.

By considering the equilibrium of forces acting at point C, write two equations relating T_1, T_2, T_3, α and β. [2]

By considering vertical equilibrium, taking upwards as positive,
$T_2 \cos \alpha - T_1 \cos \beta = 0$
$T_2 \cos \alpha = T_1 \cos \beta$ [B1]
By considering horizontal equilibrium, taking rightwards as positive,
$T_3 - (T_2 \sin \alpha + T_1 \sin \beta) = 0$
$T_3 = T_2 \sin \alpha + T_1 \sin \beta$ [B1]

(i) A student suggests that when there is an increase in the ratio of the mass hung at end A to the mass hung at end B of thread AB, the ratio of cos α to cos β would increase. Suggest how you would verify this.

Keep CD horizontal. [B1]

Describe appropriate method to increase the ratio of mass at A to mass at B (e.g. increase the mass at end A while keeping the mass at end B the same)

Determine the ratio of $\frac{\cos\alpha}{\cos\beta}$. If the ratio of cos α to cos β increases when the mass ratio increases, then the statement is true. [B1]

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2 In this experiment, you will measure the potential difference across resistor R_2 as the resistance of the circuit is varied.

(a) The Digital Multimeter (DMM) is used as a voltmeter.

Ensure that the black lead of the Digital Multimeter (DMM) is connected to the "COM" jack input, while the red lead is connected to the "V / Ω / mA" jack input.

Set the dial on the DMM to "**20 V**" mark in the "V" range.

(b) Set up the circuit as shown in Fig. 2.1. Connect one R_1 to the circuit and close the switch.

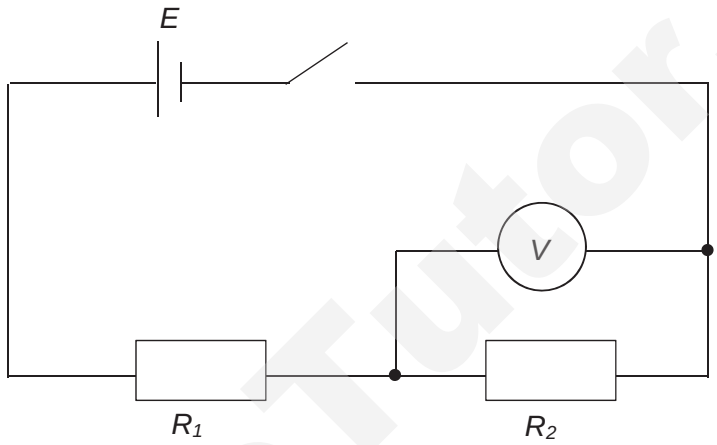

Fig. 2.1

(c) Record the potential difference across R_2, V using the voltmeter.

V measured to the correct precision with unit
Unit: V (2 d.p.)
V_1 = 2.16 V
V_2 = 2.16 V
$V_{average}$ = 2.16 V

= …….. [1]

(d) Change n, the number of resistor R_1 connected **in parallel**. Obtain three further sets of values for n and the corresponding values of V. [3]

n	V_1 / V	V_2 / V
1	1.77	1.77
2	1.94	1.94
3	2.01	2.01
4	2.04	2.04

[Evidence of repeated readings: 1 mark]
Repeated measurements for V_1 and V_2 for each value of n.

[Headings: 1 mark]
Each column heading must contain a quantity and a unit. Ignore units in the body of the table.

[Raw data: 1 mark]
All values of V_1 and V_2 to the correct precision (V_1, V_2 unit: V, 2 d.p).

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(e) Theory suggests that V and n are related by the equation

$$\frac{1}{V} = \frac{R_1}{nER_2} + \frac{1}{E}$$

where E is the e.m.f. of the power supply.

Suggest how you would determine the ratio of $\frac{R_1}{R_2}$ without measuring the resistance of the resistors directly.

Plot a graph of $\frac{1}{V}$ against $\frac{1}{n}$. [B1]

The gradient of the graph represents $\frac{R_1}{R_2E}$. Therefore $\frac{R_1}{R_2} = \text{gradient} \times E$ [B1]

Measure E using a voltmeter. [B1]

……[3]

(f) In the specification of a resistor, "tolerance" refers to the percentage error in the resistance of the resistor. The tolerance of each resistor that you use in this experiment is $\pm 5\%$, resulting in an absolute error of ΔR_1 for the resistance R_1, and ΔR_2 for the resistance of R_2.

Explain how the absolute error in the effective resistance of the circuit would change when a few R_1 are connected in series instead of being connected in parallel.

When R_1 are connected in series, the absolute error in the effective resistance $\Delta R_{effective} = n\Delta R_1 + \Delta R_2$. [M1]

When R_1 are connected in parallel, the absolute error in the effective resistance $\Delta R_{effective} = \frac{\Delta R_1}{n} + \Delta R_2$. [M1]

Therefore the absolute error in the effective resistance increases when the resistors are connected in series. [A1]

……[2]

[Total: 9 marks]

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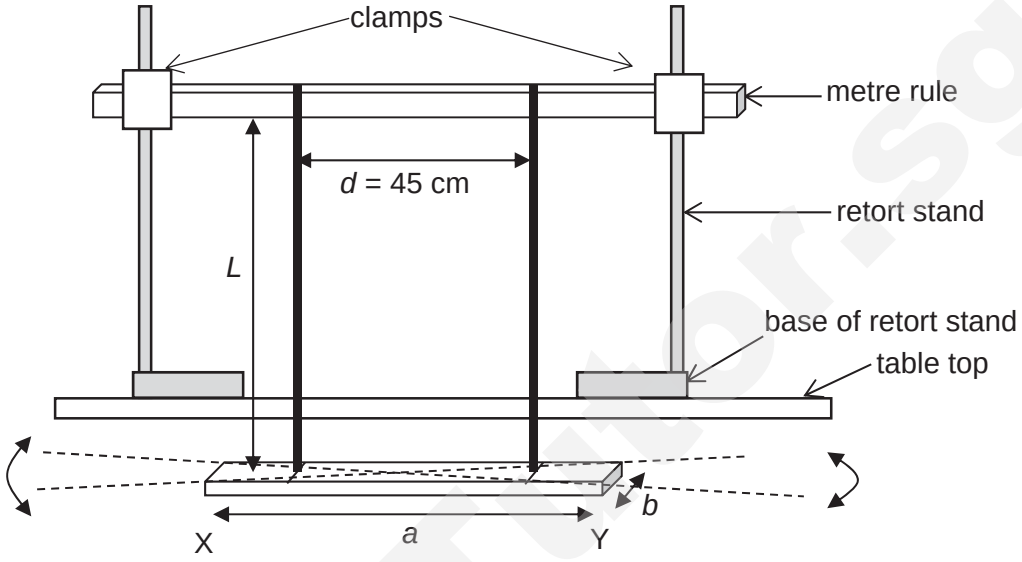
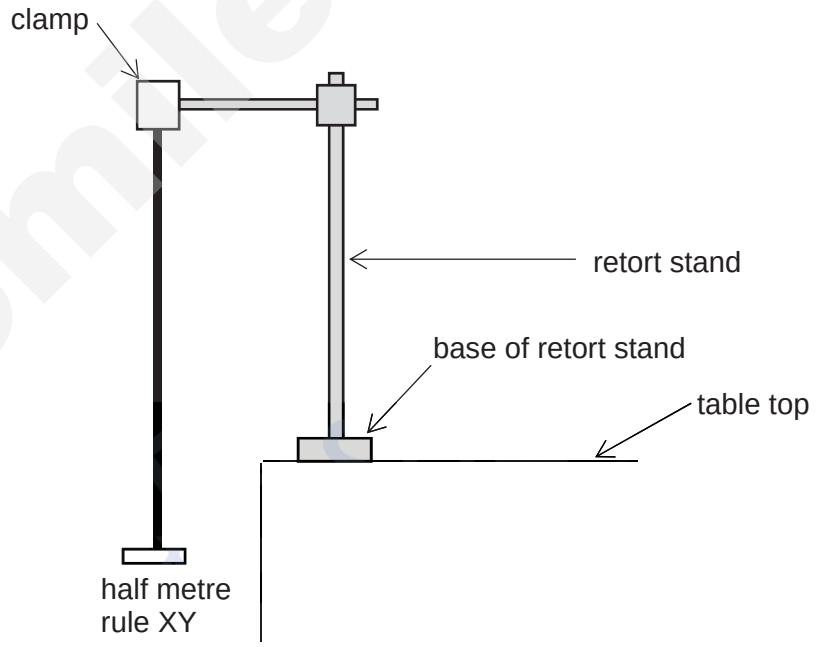
3 In this experiment, you will investigate how the period of oscillation T of a suspended half-metre rule about a vertical axis through its centre, is related to its separation L from a horizontal metre rule.

(a) Suspend a half-metre rule XY symmetrically by two exactly equal lengths of threads. XY has a length of a, and a width of b. Fig.3.1 shows the front view and Fig.3.2 shows the side view of the set up.



Front view
Fig.3.1



Side view
Fig.3.2

(b) Arrange the threads at a distance d of 45 cm apart.

(c) Ensure that the threads are vertical. Adjust L to about 100 cm.

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(d) Measure and record L.

L measured to the correct precision with unit cm – 1 d.p. m – 3 d.p.

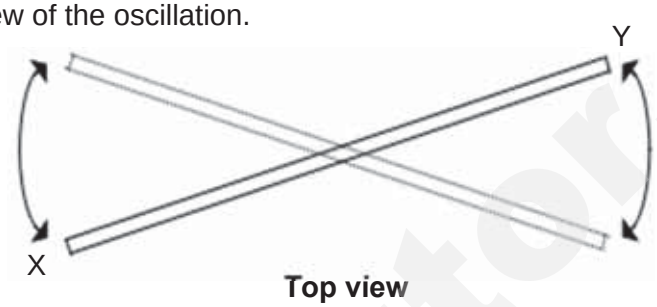
L = …….. [1]

(e) Estimate the absolute uncertainty in this value of L.

Sensible value of L with correct unit Unit: cm or m (1 s.f.) 0.2 cm or 0.002 m

absolute uncertainty = …….. [1]

(f) Give the suspended half-metre rule XY an angular displacement about a vertical axis through its centre, and set it into small angular oscillation as shown in Fig.3.1. Fig.3.3 shows the top view of the oscillation.



Top view

Fig. 3.3

(g) Determine the period T of the oscillations.

n = 20 t_1 = 25.2 s t_2 = 25.3 s $T = \frac{t_1 + t_2}{2n} = \frac{25.2 + 25.3}{2(20)} = 1.26$ s Number of oscillations n chosen such that nT is at least 10 s. Number of oscillations chosen should be stated.

T = …….. [1]

t measured to the correct precision with unit Unit: s (1 d.p.) Number of oscillations n chosen such that nT is at least 10 s. Number of oscillations chosen should be stated.

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(h) Vary L and repeat **(f)** and **(g)** to obtain further sets of values for L ranging from 20.0 cm to 100.0 cm, and the corresponding values of T. [7]

[Evidence of repeated readings: 1 mark]
Repeated measurements for t_1 and t_2 for each value of L.
Number of oscillations n chosen such that nT is at least 10 s.
Number of oscillations chosen should be stated.

[Method: 2 marks]

- Award 2 marks if candidate has successfully collected 6 or more sets of data without assistance / intervention.
- Award 1 mark if candidate has successfully collected 5 sets of data without assistance / intervention.
- Award 0 mark if candidate has successfully collected 4 or fewer sets of data without assistance / intervention.
- Deduct 1 mark if candidate requires some assistance / intervention but has been able to do most of the work independently.
- Deduct 2 marks if candidate has been unable to collect data without assistance / intervention.
- Deduct 1 mark if out of range for first and last value of <t>
- Deduct 2 marks if the trend is incorrect
- Maximum deduction of 2 marks

[Headings: 1 mark]
Layout: column headings (raw data and calculated quantities: L, t, T and T^2.
Each column heading must contain a quantity and a unit. Ignore units in the body of the table.
Column for n (number of oscillations timed) may be used if appropriate (though no units are expected for this column).

[Raw data: 1 mark]
All values of L, t_1 and t_2 to the correct precision (1 d.p.).

[Processed data – no. of d.p. / s.f: 1 mark]
For each calculated value of T and T^2, the number of s.f. should be the same as the number of s.f. in the raw data.
No mark if T^2 is not present.

[Processed data – accuracy: 1 mark]
Correctly calculated values of T and T^2.
No mark if T^2 is not present.

No. of oscillations n = 20

L / cm	t_1 / s	t_2 / s	T / s	T^2 / s^2
20.0	11.8	11.7	0.588	0.345
40.0	16.4	16.2	0.815	0.664
50.0	18.0	18.0	0.900	0.810
60.0	19.7	19.7	0.985	0.970
80.0	22.7	22.5	1.13	1.28
100.0	25.2	25.3	1.26	1.59

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(i) It is suggested that *T and L* are related by the equation

$$g = \frac{16\pi^2(a^2 + b^2)}{12d^2}\frac{L}{T^2}$$

Plot a suitable graph and hence determine the acceleration due to gravity, *g*. [6]

[Linearising the equation: 1 mark]
By plotting a graph of T^2 against L, a straight line graph should be obtained with gradient $\frac{16\pi^2(a^2 + b^2)}{12d^2g}$ and y-intercept = 0.
No mark if the axes are inverted.

[Graph: layout (choice of scale and labeling of axes): 1 mark]
Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.

Scales must be chosen so that the plotted points occupy at least half the graph grid in both *x* and *y* directions.

Scales must be labeled with the quantity which is being plotted.

No mark if the axes are inverted.

[Graph: plotting of points: 1 mark]
All observations must be plotted.
Work to an accuracy of half a small square.

[Graph: trend line (ability to draw line of best fit): 1 mark]
Straight line of best fit – judge by scatter of points about the candidate's line.
There must be a fair scatter of points either side of the line.

- If the data points are close to a straight line or a curve, there should be about the same number of points on either side of the line/ curve. Furthermore, in each half of the line/curve there should be the same number of points above it as below. The best straight line or curve is drawn by visual estimation with the aid of a transparent ruler.

[Interpretation of graph – gradient : 1 mark]
Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square.
Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).

[Drawing conclusion : 1 mark]
Value of *g* calculated correctly with unit.

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(j) Comment on any anomalous data or results you may have obtained. Explain your answer.

There is no anomalous data as all points are fairly scattered about the best fit line. *OR*
There are anomalous points at (_ , _) and (_ , _) as they lie further away from the best fit line as **compared to all the other points**.

.....
....[1]

(k) State one significant source of error in this experiment.

.....

.....

.....[1]

(l) Suggest one improvement that could be made to the experiment to address the error identified in **(k)**. You may suggest the use of other apparatus or different procedures.

.....

.....

.....[1]

(k) Significant source of error	(l) Improvement
1) The vertical strings might shift during oscillation. ⇒ affect period *T*	1) Fix the strings using adhesive tape.
2) The ruler wobbles and does not oscillate about the vertical axis; unsteady oscillation. ⇒ affect period *T*	2) Switch off fans to reduce draft; ensure ruler is horizontal with CG of ruler symmetrically between the two vertical strings.
3) Metre rule is not suspended horizontally. ⇒ affect *L* and *T*	3) Use a spirit level meter to ensure the ruler is horizontal.

(m) On the graph grid on page 9, sketch a second graph to represent the results if the distance between two threads *d* is increased. Label this graph Z. [1]

When *d* increases, the gradient decreases, but y-intercept remains the same.
[1 mark]

[Total: 20 marks]

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4 The history of solar energy is as old as humankind. In 1954, some scientists in the United States produced electricity from the sun. They invented photovoltaic cells, which capture the sun's energy and convert it into electricity. A photovoltaic cell is an electric cell made from two layers of different materials that can produce an electric current when light of certain frequencies shines on the cell. A solar panel is a collection of photovoltaic cells.

The frequency of the light falling on the solar panel can be varied by placing different colour filters in front of the light source as shown in Fig.4.1.

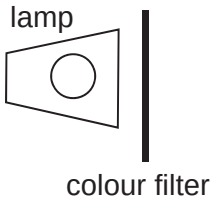


Fig.4.1

Design an experiment to investigate how the power generated by a solar panel depends on the frequency of the light falling on it.

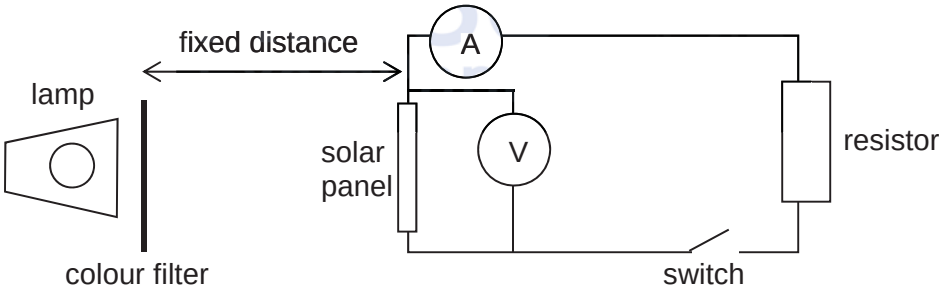
The equipment available includes the following:

Solar panel	Resistors
Colour filters	Switch
Lamp	Stopwatch
Spectrometer with diffraction grating	Rule
Ammeter	Micrometer screw gauge
Voltmeter	

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the frequency of the light used is to be measured,
(d) how the power generated by the solar panel is to be measured,
(e) the control of variables,
(f) any precautions that would be taken to improve the accuracy, precision and safety of the experiment.

Diagram



[Total: 12 marks]

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Procedure:

1. Set up as shown in the diagram.
2. [P1] Shine direct light through the colour filter at the solar panel. (Write this statement or draw in the diagram to illustrate this idea)
3. [C1] The lamp and filter is placed at a fixed distance measured using a ruler from the solar panel.
4. [C2] Solar panel is placed perpendicular to direction of light so that incident angle of light does not affect intensity. [C3] Ensure that the thickness of each filter is the same by measuring using micrometer screw gauge.
5. [A1] With the room lights switched off / In a dark room, switch on the power supply to the lamp.
6. [M1] The frequency f of the light through each filter is determined by using the spectrometer and diffraction grating. [P2] By taking note of the spacing d of the lines on the grating, angle θ on the spectrometer, and the order n of the diffracted light being observed, f can be calculated using $d \sin\theta = \frac{nc}{f}$, where c is the speed of light.
7. [P3] Connect ammeter in series with the solar panel, and a voltmeter across the solar panel (Write this statement or draw in the diagram)
8. [M2] Measure the current passing through the solar panel I using ammeter, and [M3] measure the potential difference across the solar panel V using the voltmeter.
9. [P4] Calculate the power generated by the solar panel, $P = IV$.
10. [A3] Repeat the readings of current through the solar panel and potential difference across the lamp for the same frequency of light by switching on and then off the lamp / removing and then putting back the colour filter / switching off and on the circuit connected to the solar panel.
11. Replace the filter with another colour and repeat steps (8) to (10).
12. [A2] Switching off lamp between readings to prevent solar panel from heating to maintain constant conductivity.
13. [D1] Assume $P = kf^n$, plot a graph of lg P against lg f. [D2] If a straight line graph is obtained with gradient n and y-intercept lg k, then the hypothesis is true.

Safety precautions:

- [S1] Handle the electrical circuit with care if potential difference is high (e.g. Dry hands / wear gloves when handling the circuit) so as to prevent electrocution.
- [S2] Wear protective eyewear to avoid eye injury due to intense light / in case of breaking the filter.

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Suggested Mark Scheme [PMACDS]
[Note: For each category, always think systematically of points related to IV and DV respectively.]

*Basic **P**rocedure [max 4]*

- P1: Shine direct light through the colour filter at the solar panel.
- P2: **[IV]** (By taking note of the spacing *d* of the lines on the grating, angle *θ* on the spectrometer, and the order *n* of the diffracted light being observed,) *f* can be calculated using $d \sin\theta = \frac{nc}{f}$, where *c* is the speed of light.
- P3: **[Processed DV]** Connect ammeter in series with the solar panel, and a voltmeter across the solar panel.
- P4: **[Processed DV]** Calculate the power generated by the solar panel, $P = IV$.

[Note: All formulae used for processed data should be explicitly written out.]

***M**easurement [max 3]*

- M1: **[IV]** The frequency *f* of the light through each filter is determined by using the spectrometer and diffraction grating.
- M2: **[DV]** Measure the current passing through the solar panel *I* using ammeter.
- M3: **[DV]** Measure the potential difference across the solar panel *V* using the voltmeter.

[Note: All steps involved in measurement should be explicitly written out.]

*Additional detail to improve **A**ccuracy [max 2]*

- A1: **[DV]** With the room lights switched off / In a dark room, switch on the power supply to the lamp.
- A2: **[DV]** Switching off lamp between readings to prevent solar panel from heating.
- A3: **[DV]** Repeat the readings of current through the solar panel and potential difference across the lamp for the same frequency of light by switching on and then off the lamp / removing and then putting back the colour filter / switching off and on the circuit connected to the solar panel.

[Note: Always explain exactly how (including equipment) you would improve accuracy in measurement of IV and DV.]

***C**ontrol of variables [max 2]*

- C1: The lamp and filter is placed at a fixed distance from solar panel, by measuring using a ruler / not moving the position of the lamp, filter and solar panel.
- C2: Solar panel is placed perpendicular to direction of light so that incident angle of light does not affect intensity.
- C3: Ensure that the thickness of each filter is the same by measuring using micrometer screw gauge.

[Note: Always explain exactly how (including equipment) you would keep the respective control variables constant.]

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Suggested Mark Scheme [PMACDS]

***D**ata analysis [max 2]*

- D1: Assume $P = kf^n$, plot a graph of lg P against lg f.
- D2: If a straight line graph is obtained with gradient n and y-intercept lg k, then the hypothesis is true.

[Note: Always use general equation instead of $P = kf$.]

***S**afety considerations [max 2]*

- S1: Handle the electrical circuit with dry hands / wear gloves, so as to prevent electrocution.
- S2: Wear protective eyewear to avoid eye injury due to intense light / in case of breaking the filter.

[Note: Focus on key safety considerations, and explain proactive actions to do with rationale.]

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END OF PAPER

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Class	Index Number	Name
16S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2017
Preliminary Examination

PHYSICS, Higher 2 **9749/01**

Paper 1 Multiple Choice **19th September 2017**
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil..
Do not use staples, paper clips, glue or correction fluid.
Write your name, index number and Civics Group the Answer Sheet in the spaces provided.

There are **thirty** questions in this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Total	/ 30

This document consists of **15** printed pages including this page.

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Data

speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}

$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge, $e = 1.60 \times 10^{-19}$ C

the Planck constant, $h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg

rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

molar gas constant, $R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant, $k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

acceleration of free fall, $g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

hydrostatic pressure, $p = \rho g h$

gravitational potential, $\phi = -\dfrac{Gm}{r}$

temperature, $T/\text{K} = T/^{\circ}\text{C} + 273.15$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

mean translational kinetic energy of an ideal gas molecule, $E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$v = \pm \omega \sqrt{x_0^2 - x^2}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + ...$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + ...$

electric potential, $V = \dfrac{Q}{4\pi\varepsilon_0 r}$

alternating current/voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire, $B = \dfrac{\mu_0 I}{2\pi d}$

magnetic flux density due to a flat circular coil, $B = \dfrac{\mu_0 NI}{2r}$

magnetic flux density due to a long solenoid, $B = \mu_0 nI$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \dfrac{\ln 2}{t_{1/2}}$

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1 Frankie times the oscillations of a simple pendulum but accidentally starts by counting "1", instead of "0", when the bob is released and finishes at a count of "10".

What is the percentage error in the student's calculation of the period due to this mistake?

A 10% low **B** 10% high **C** 11% low **D** 11% high

2 Cynthia found that the magnetic flux density B at the centre of a solenoid is given by $B = \mu_o nI$ where μ_o is the permeability of vacuum, n is the number of turns per unit length and I is the current in the solenoid.

Which of the following gives the correct SI units of the permeability of vacuum?

A kg m^2 s^{-2} A^{-2}
B kg m s^{-2} A^2
C kg m^2 s A^{-2}
D kg m s^{-2} A^{-2}

3 A projectile is launched at an angle θ above the horizontal. Ignoring air resistance, what fraction of its initial kinetic energy does the projectile have at the top of its trajectory?

A cos θ
B $\cos^2 \theta$
C sin θ
D 0, since the projectile is momentarily at rest at maximum height

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4 The velocity - time (v – t) graph of a particle is shown in Fig. 4

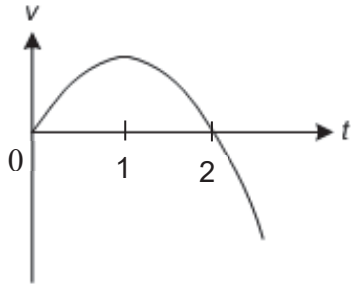
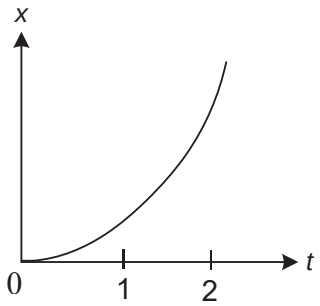
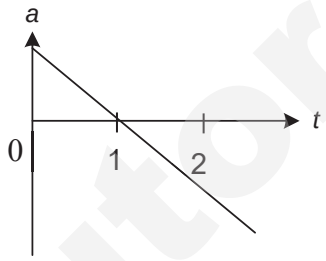


Fig. 4

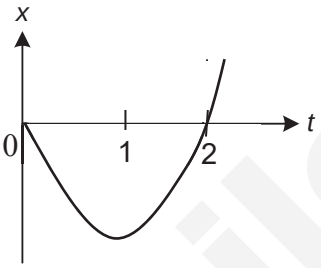
Which of the following pairs of graphs best represents the displacement - time (x - t) and acceleration - time (a - t) graphs for the particle?

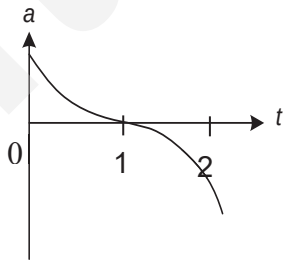
A



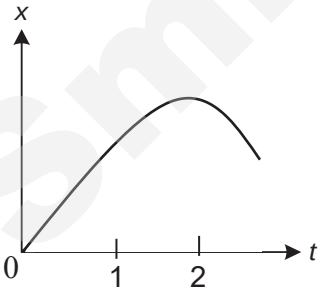


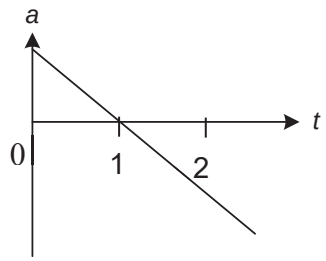
B



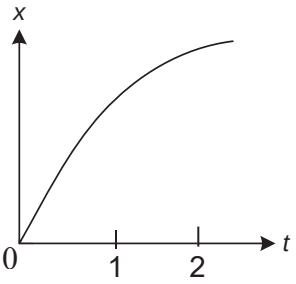


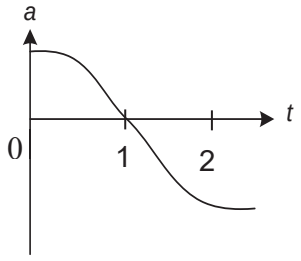
C





D





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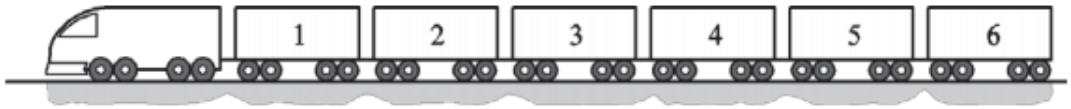
5 A train consisting of six trucks each of mass 6.0×10^4 kg is pulled at a constant speed by a locomotive of mass 24×10^4 kg along a straight horizontal track. The horizontal force resisting the motion of each truck is 4000 N.



The coupling between trucks 2 and 3 snaps.

What is the initial acceleration of the locomotive?

A 0.022 m s^{-2}
B 0.044 m s^{-2}
C 0.067 m s^{-2}
D 0.133 m s^{-2}

6 Two boats, each of mass M, are at rest adjacent to each other on calm water. A boy, of mass m, jumps from boat B to boat A.



Neglecting any dissipative forces the boats may experience, the ratio of the final speed of boat A to that of boat B is

A 1 : 1
B m : M
C $(m + M)$: M
D M : $(M + m)$

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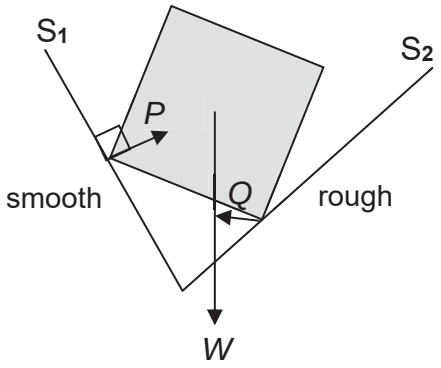
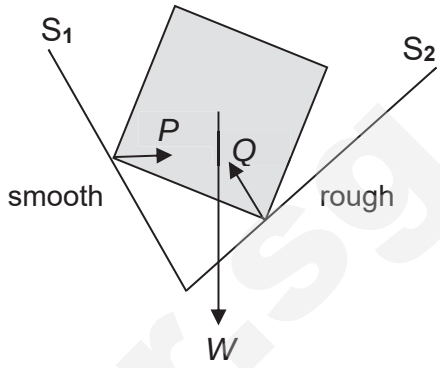
7 Two straight edges of a uniform cube are leaning on smooth surface S_1 and rough surface S_2 and is about to slip. If the cube has weight W and the contact forces on the cube by surface S_1 and S_2 are P and Q respectively, which one of the following diagrams shows the possible directions of these forces?

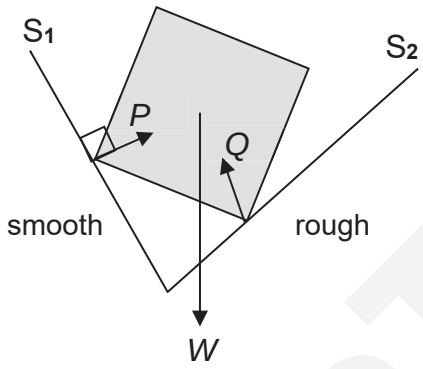
A



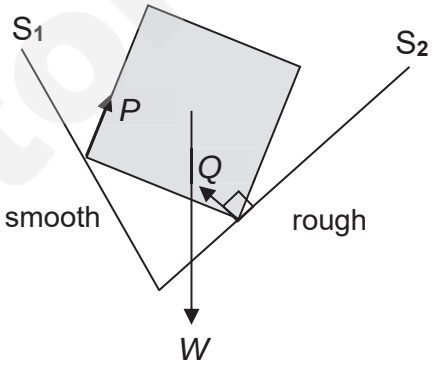
B



C

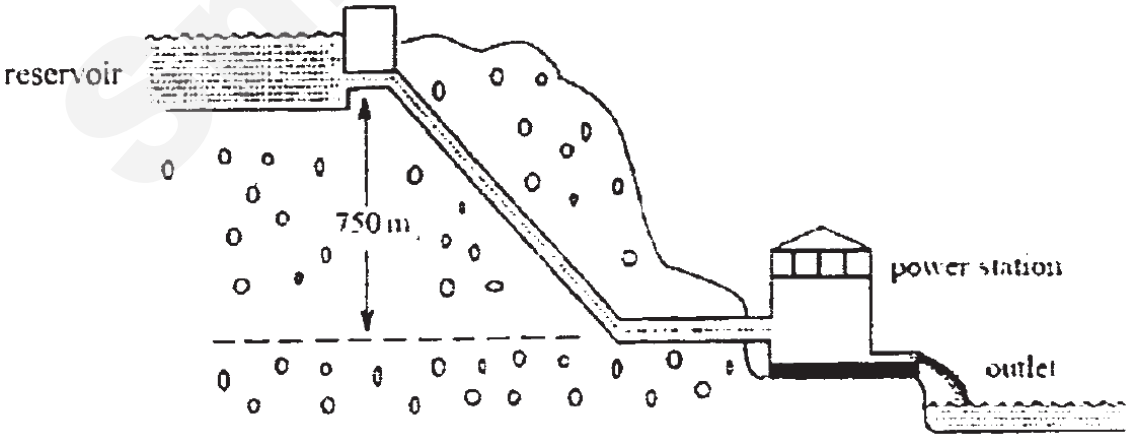


D



8 This question is about a hydroelectric power station. Water is supplied from a reservoir which is 750 m above the power station turbines, as shown in the diagram. The water passes through its turbines at a rate of 1.4 $m^3\ s^{-1}$.

(Density of water = 1000 kg m^{-3})



If the efficiency of the power station is 20%, what is its power output?

A 2.1 kW
B 2.1 MW
C 5.2 kW
D 52 MW

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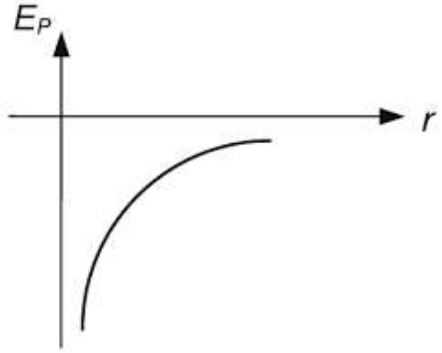
9 The gravitational potential energy E_P of a body varies with its distance r from the centre of a planet as shown in the diagram below.



What does the gradient at any point on the curve represent?

A The gravitational potential at that value of r
B The gravitational field strength at that value of r
C The force pulling the body towards the planet
D The acceleration of the body towards the planet

10 Two spherical planets have the same average density and respective radii R_1 and R_2. The ratio of the gravitational field on the surface of the first planet to that of the second is

A $R_1 : R_2$
B $R_2 : R_1$
C $R_1^2 : R_2^2$
D $R_2^2 : R_1^2$

11 A gas with a total mass of 1.60 kg exerts a pressure of 1.00×10^5 Pa in a container of volume 0.500 m^3.

What is the root-mean-square speed of the gas molecules?

A 250 $m\ s^{-1}$
B 286 $m\ s^{-1}$
C 300 $m\ s^{-1}$
D 306 $m\ s^{-1}$

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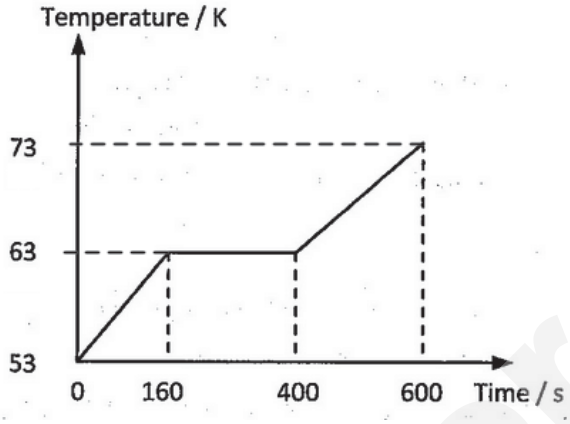
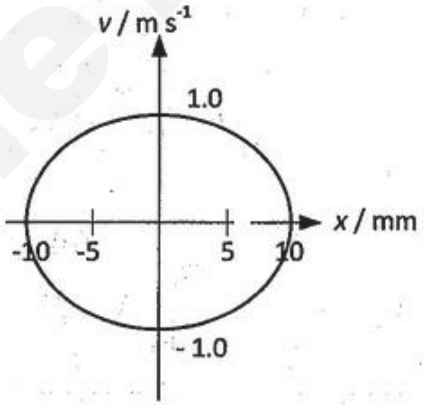
12 The graph shows how the temperature of a specimen changes with time when heated by a constant power source.

Given that the specific heat capacity of the specimen when in the liquid state is 1.60×10^3 J kg^{-1} K^{-1}, what is the heat capacity of the specimen when in the solid state?



A 1.28×10^3 J kg^{-1} K^{-1}
B 1.40×10^3 J kg^{-1} K^{-1}
C 1.92×10^3 J kg^{-1} K^{-1}
D 2.00×10^3 J kg^{-1} K^{-1}

13 The graph shows the velocity variation with displacement of a body undergoing simple harmonic motion.



What is the frequency of the oscillation?

A 10.9 Hz
B 15.9 Hz
C 50.5 Hz
D 100 Hz

14 A force that varies sinusoidally is applied to a system that is lightly damped.

Which of the following must be true of the force for resonance to occur?

A It must always be in anti-phase with the oscillations of the system.
B Its direction must always be in the direction of motion of the oscillations of the system.
C Its frequency must be equal to the frequency of oscillation of the system.

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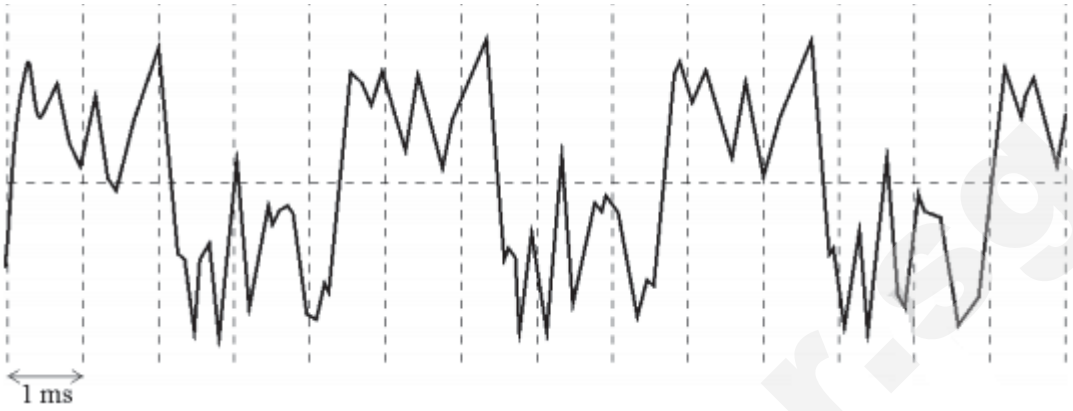
D Its amplitude must be equal to the amplitude of oscillation of the system

15 A musical note played by a clarinet is recorded. The signal is shown in the diagram below with the time-scale indicated.



What is the fundamental frequency of the note played by the clarinet?

A 77 Hz
B 120 Hz
C 230 Hz
D 2200 Hz

16 The diagram below shows an instantaneous position of a string as a transverse progressive wave travels along it from *right* to *left*.



Which of the following correctly shows the directions of the velocities of the points 1, 2 and 3 on the string?

	1	2	3
A	↑	↓	↑
B	↓	↑	↓
C	←	←	←
D	→	→	→

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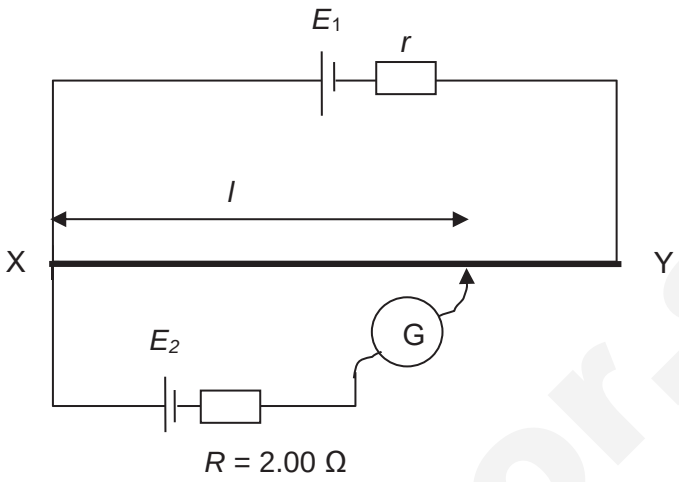
17 A potentiometer consists of a 1.000 m long resistance wire **XY** in series with a battery of e.m.f. E_1 = 9.00 V and internal resistance r = 1.42 Ω. The resistance of **XY** is 8.30 Ω.

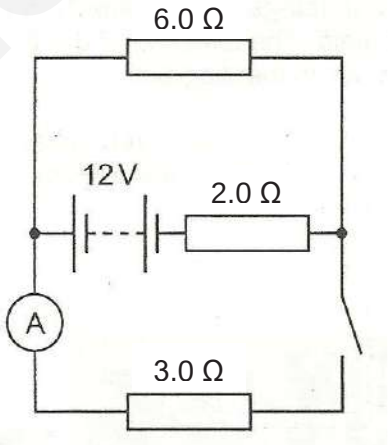
Determine the emf of cell E_2 if the balance length l is found to be 0.745 m.



A 0.636 V
B 2.72 V
C 5.73 V
D 9.00 V

18 In the circuit, the battery has an e.m.f. of 12 V and an internal resistance of 2.0 Ω. The ammeter has negligible resistance.

The switch is closed.



What is the reading on the ammeter?

A 0.50 A **B** 1.0 A **C** 1.3 A **D** 2.0 A

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19 Two parallel plates are connected to an E.H.T. (Extra high Tension) of 4.5 kV. Electric breakdown occurs when the separation of the plates is reduced to 1.5 mm.

Estimate the maximum acceleration of an electron between the plates at this separation.

A 1.0×10^{9} m s^{-2}
B 1.2×10^{12} m s^{-2}
C 1.6×10^{15} m s^{-2}
D 5.3×10^{17} m s^{-2}

20 The diagram Fig. 20.1 below shows an insulating rod with equal and opposite charges at its ends, placed in a non-uniform electric field for which field lines (lines of force) are shown.

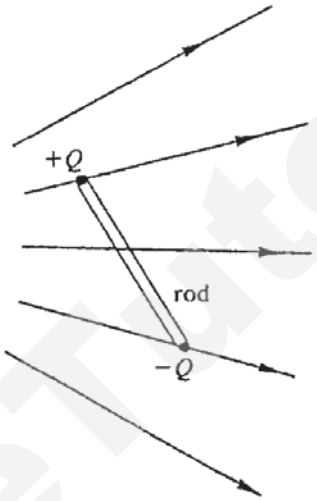

Fig. 20.1

The rod experiences

A a resultant force and a net clockwise moment.
B a resultant force and a net anti-clockwise moment.
C a resultant force only.
D a net moment only.

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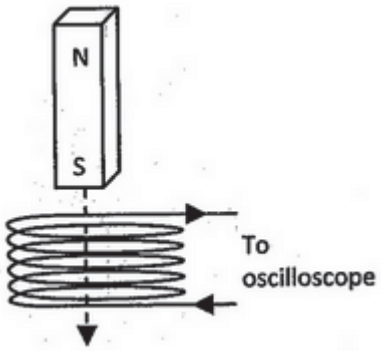
21 A wire coil with its plane horizontal is connected to an oscilloscope. A long magnet falls from rest through the coil along its axis.



The trace observed on the oscilloscope screen is best represented by

A



B



C

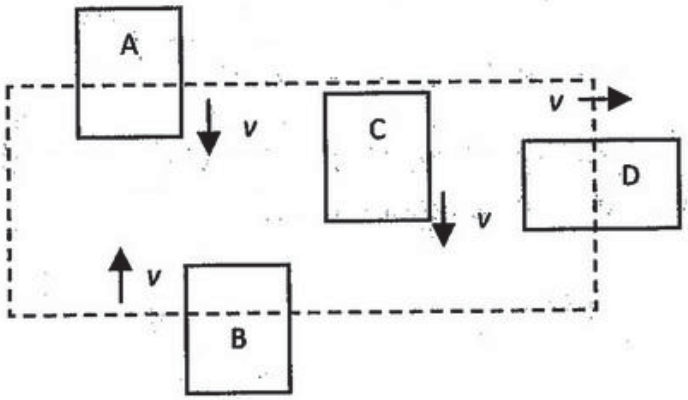


D



22 A uniform magnetic field *B* permeates the rectangular region shown by the dotted line. The direction of *B* is pointing into the page.

Which of the wire loops, moving with velocity *v*, has a current that flows in the clockwise direction?



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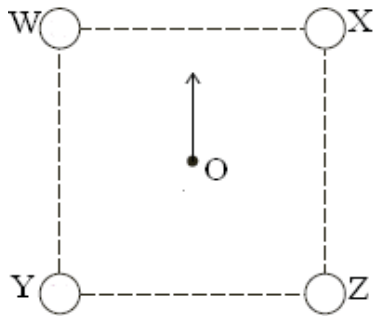
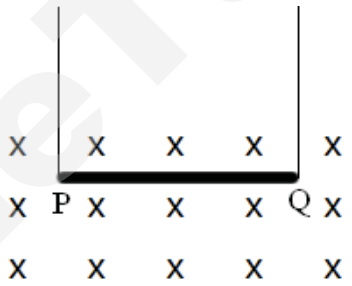
23 Parallel conductors **WXYZ** carry the same magnitude of currents and pass vertically through the four corners of a square.



Which of the following is the current directions of the current in order to produce a resultant magnetic field in the direction shown at **O**, the centre of the square?

	Into the page	Out of the page
A	W, X	Y, Z
B	W, Y	X, Z
C	X, Z	W, Y
D	Y, Z	W, X

24 A wire **PQ** of 60 cm long and of mass 10 g is suspended by a pair of leads in a magnetic field of flux density 0.40 T.



What is the magnitude and direction of current flowing in the wire if the net tension in the leads is negligible?

	Magnitude	Direction
A	0.409 A	P to Q
B	0.354 A	P to Q
C	0.354 A	Q to P
D	0.409 A	Q to P

25 A transformer with turns ratio of primary to secondary coil of 20:1 is 95% efficient due to joule heating effects. A 240 V alternating voltage is connected to the primary coil and a 5.0 Ω resistor is connected to the secondary coil.

What is the current flowing in the primary coil?

A 2.40 A
B 0.120 A
C 0.126 A
D 48.0 A

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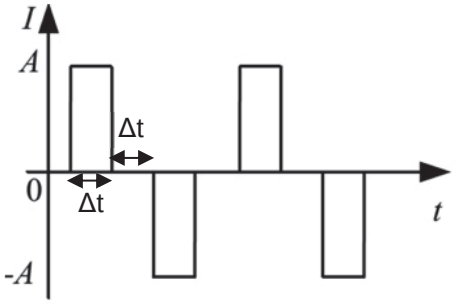
26 An alternating current with equal time interval during each constant current interval is shown below.



What is the root-mean-square current?

A $A/\sqrt{2}$ **B** $A/2$ **C** $A/3$ **D** $A/4$

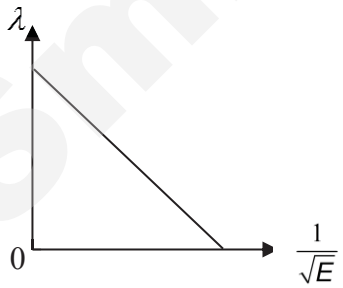
27 Light quanta each of energy 3.5×10^{-19} J fall on the cathode of a photocell. The current through the cell is just reduced to zero by applying a reverse voltage to make the cathode 0.25 V positive with respect to the anode.

The minimum energy required to remove an electron from the cathode is

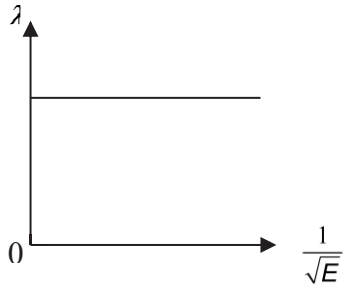
A 2.9×10^{-19} J
B 3.1×10^{-19} J
C 3.5×10^{-19} J
D 3.9×10^{-19} J

28 An electron with kinetic energy E has a de Broglie wavelength of λ. Which of the following graphs correctly represents the relationship between λ and E?

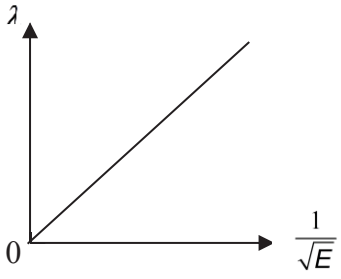
A



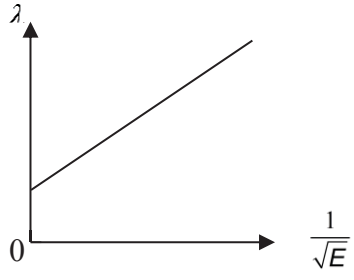
B



C



D



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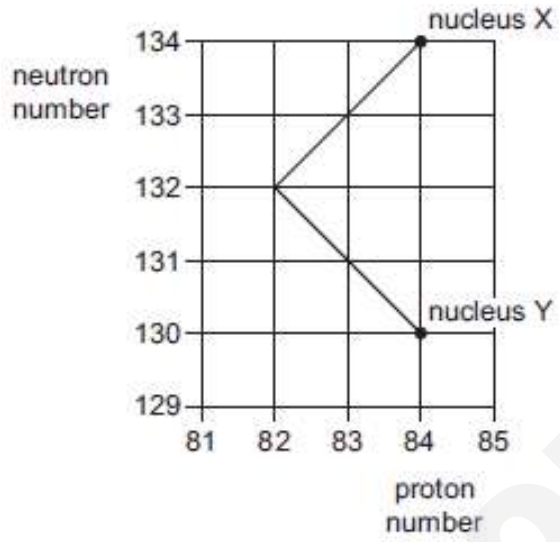
29 The graph of neutron number against proton number represents a sequence of radioactive decays.



Nucleus **X** is at the start of the sequence and, after the decays have occurred, nucleus **Y** is formed.

What is emitted during the sequence of decays?

A one α-particle followed by one β-particle
B one α-particle followed by two β-particles
C two α-particles followed by two β-particles
D two β-particles followed by one α-particle

30 The nuclear reaction $P + Q \rightarrow X + Y$ proceeds with a release of energy. Which of the following statement must be correct?

A Mass of X and Y is larger than mass of P and Q.
B Momentum of X and Y is larger than momentum of P and Q.
C Total binding energy of X and Y is larger than total binding energy of P and Q.
D Binding energy per nucleon of both X and Y are larger than binding energy per nucleon of P or Q.

End of paper

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Class	Index Number	Name
16S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2017
Preliminary Examination

PHYSICS, Higher 2 **9749/02**

Paper 2 Structured Questions **14th September 2017**
2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 9
2	/ 10
3	/ 10
4	/ 10
5	/ 10
6	/ 10
7	/ 21
Total	/ 80

This document consists of **23** printed pages including this page.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = u\,t + \frac{1}{2}\,a\,t^2$
	$v^2 = u^2 + 2\,a\,s$
work done on/by a gas,	$W = p\,\Delta V$
hydrostatic pressure,	$p = \rho\,g\,h$
gravitational potential,	$\phi = -\dfrac{Gm}{r}$
temperature,	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{1/2}}$

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1 **(a)** Distinguish between a couple and the torque of a couple.

……

……

…… [2]

(b) A uniform plank of mass 1.00 kg is held up by 2 identical, massless and inextensible strings, each 1.00 m from the centre of the plank. A block of mass 4.50 kg is supported by the plank at a distance of 1.50 m away from the left string as shown in Fig. 1.1 below (not drawn to scale). The size of the block is insignificant compared to the length of the plank.

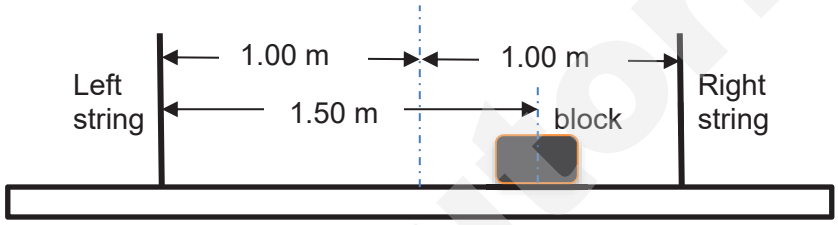

Fig. 1.1

Calculate the tension in each string.

tension in left string = …..…… N

tension in right string = …… N [3]

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(c) The National Day Parade last month saw a light show performed by 300 unmanned drones developed by Intel, called the Shooting Star drones. Each of these multirotor drones has a mass of 330 grams and four sets of propellers, as shown in Fig. 1.2, and the propellers cannot tilt like in helicopter rotors.



Fig. 1.2

When such a drone is in a stable hover, propellers **1** and **2** are spinning clockwise and anti-clockwise respectively as shown in the top-view diagram of the drone in Fig. 1.3.

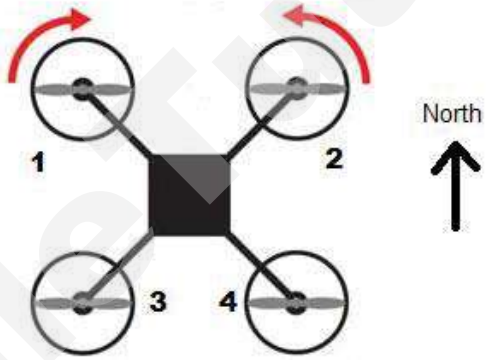

Fig. 1.3

(i) Draw in Fig. 1.3 above curved arrows to show the spins for propellers **3** and **4**. [1]

(ii) Explain how the drone can hover in the sky.

……..

…… [1]

(iii) Explain, in terms of the speeds of the propellers, how the drone can fly forward (Northward) from a hovering position without a change in height.

……...

……...

……...

……...

…… [2]

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2 **(a)** Use Newton's laws of motion to explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

……

……

……

…… [3]

(b) A massless spring of force constant k = 78.4 N m^{-1} is fixed on the left side of a level track. A block of mass m = 0.50 kg is pressed against the spring and compresses it by a distance d as shown in Fig. 2.1. The block is then released from rest and travels toward a circular loop-the-loop of radius R = 1.5 m.

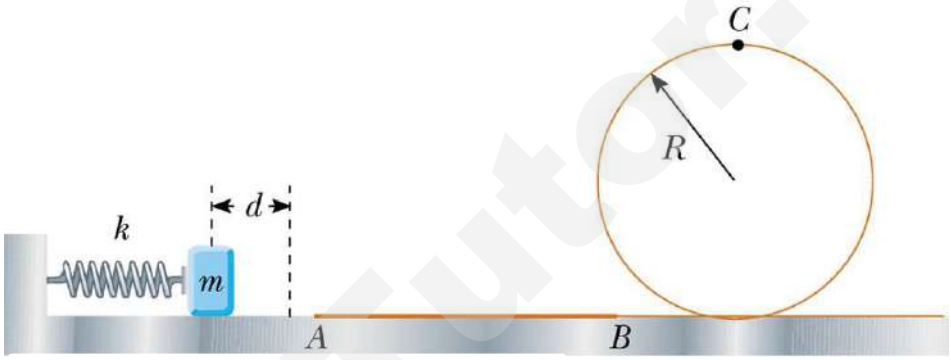

Fig. 2.1

The entire track and the loop-the-loop are frictionless except for the section of track between points **A** and **B**.

Given that the friction between the block and the track along **AB** is 1.47 N and the length of **AB** is 2.5 m, determine the minimum compression d of the spring that enables the block to just make it through the loop-the-loop at point **C**.

minimum compression = …… m [3]

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(c) An elastic cord has an un-extended length of 13.0 cm. One end of the cord is attached to a fixed point **C**. A small mass of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 2.1.

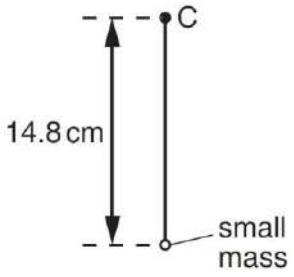

Fig. 2.1

The cord and mass are now made to rotate at *constant* angular speed ω in a vertical plane about point **C**. When the cord is vertical and above **C**, its length is the un-extended length of 13.0 cm, as shown in Fig. 2.2.

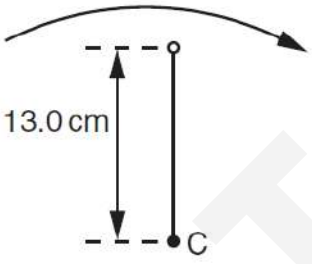

Fig. 2.2

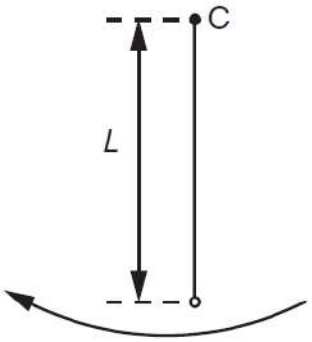

Fig. 2.3

The cord and mass rotate so that the cord is vertically below **C**, as shown in Fig. 2.3.

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Calculate the length L of the cord, assuming it obeys Hooke's law.

L = …… cm [4]

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3 A uniform beam is clamped at one end. A metal block of mass m is fixed to the other end of the beam causing it to bend, as shown in Fig. 3.1.

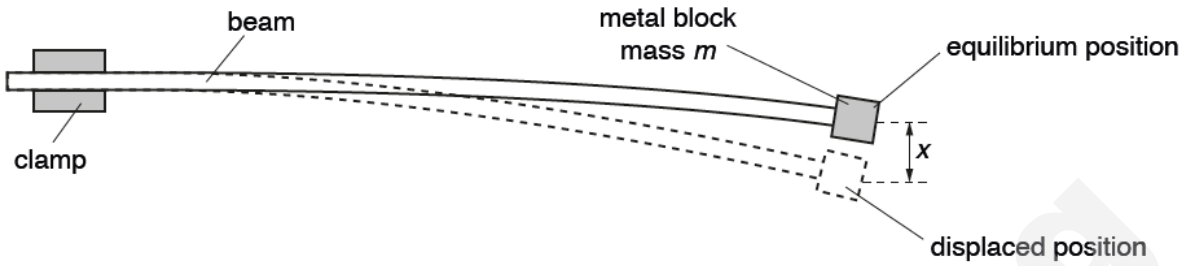

Fig. 3.1

The block is given a small vertical displacement and then released so that it oscillates with an acceleration a given by the expression

$$a = -\frac{k}{m}x$$

where k = 4.0 kg s^{-2} and m = 0.25 kg.

(a) Explain how it can be deduced from the expression that the block moves with simple harmonic motion.

……

……

…… [2]

(b) Calculate the period of the oscillation.

period =…… s [2]

(c) The initial amplitude of the oscillation of the block is 3.0 cm. Calculate the maximum speed of the object.

maximum speed =…… m s^{-1} [2]

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(d) Over a certain interval of time, the maximum kinetic energy of the oscillations in **(c)** is reduced by 20%. It may be assumed that there is negligible change in the angular frequency of the oscillations.

Determine the amplitude of oscillation.

amplitude =…… m [2]

(e) Permanent magnets are now positioned so that the metal block oscillates between the poles, as shown in Fig. 3.2.

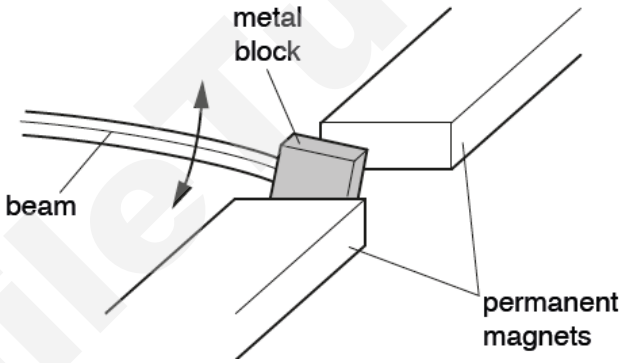

Fig. 3.2

The block is made to oscillate with the same initial amplitude as in **(c)**. Use energy conservation to explain why the energy of the oscillations decreases more rapidly than in **(d)**.

……..

……..

……..

…… [2]

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4 **(a)** Define *electric field strength*.

……

……

…… [1]

(b) The diagram below shows the equipotential lines (dotted lines) due to two charges (solid dots).

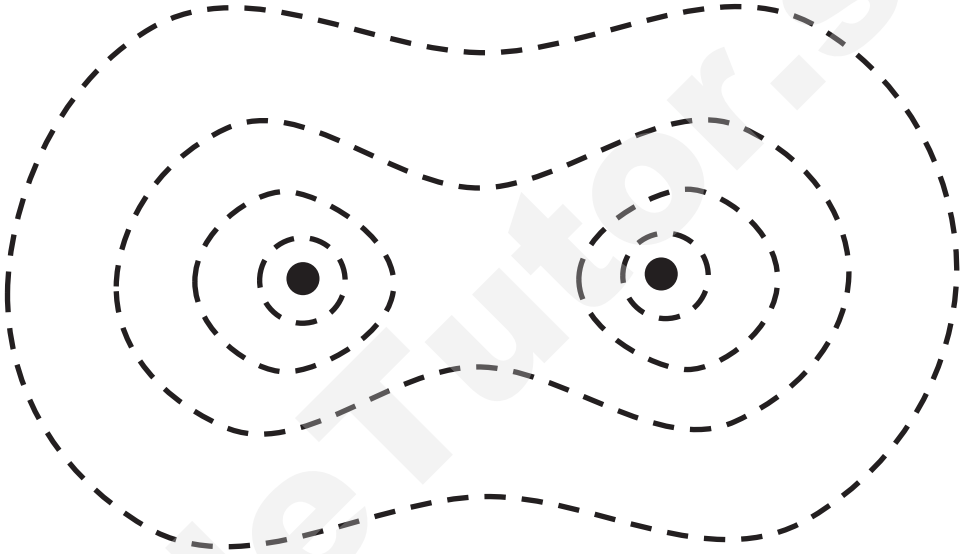

Fig.4.1

(i) State whether the two charges are like or unlike charges and comment on the relative magnitude of the two charges. Explain your reasoning.

……

……

……

…… [2]

(ii) State the angle between an equipotential line and an electric field line. Explain your answer.

……

……

…… [2]

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(iii) Hence, draw on Fig. 4.1 the electric field lines of these two charges. You do not need to indicate the direction of the field lines.

[2]

(c) Two charged spheres with charges q_1 and q_2 are fixed at their positions as shown in Fig. 4.2.

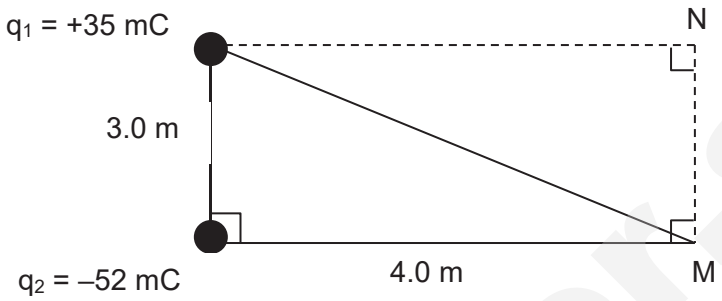

Fig. 4.2

Determine the work done by an external force on a third charged sphere q_3 of +4.5 μC as q_3 is moved from point M to point N.

work done = …… J [3]

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5 **(a)** State Faraday's law of electromagnetic induction.

……

…… [1]

(b) The diameter of the cross-section of a long solenoid with 15 turns is 3.2 cm, as shown in Fig. 5.1

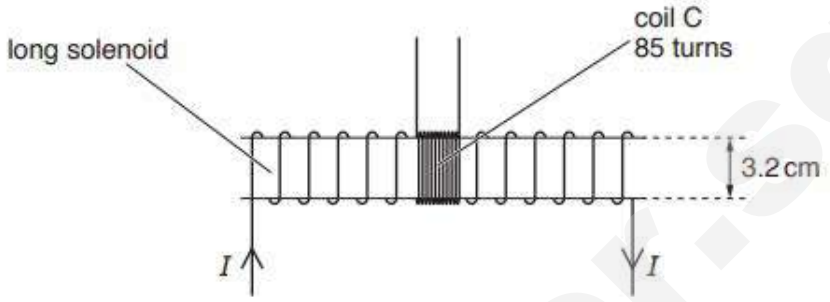

Fig. 5.1

A coil **C**, with 85 turns of wire, is wound tightly around the centre region of the solenoid. The magnetic flux density B, in tesla, at the centre of the solenoid is given by the expression

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

(i) Calculate, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil **C**.

magnetic flux linkage = …… Wb [1]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s. Calculate the mean e.m.f. induced in coil **C**.

e.m.f. induced = …… V [2]

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(iii) The current I in the solenoid in **(b)(i)** is now varied with time t as shown in Fig. 5.2.

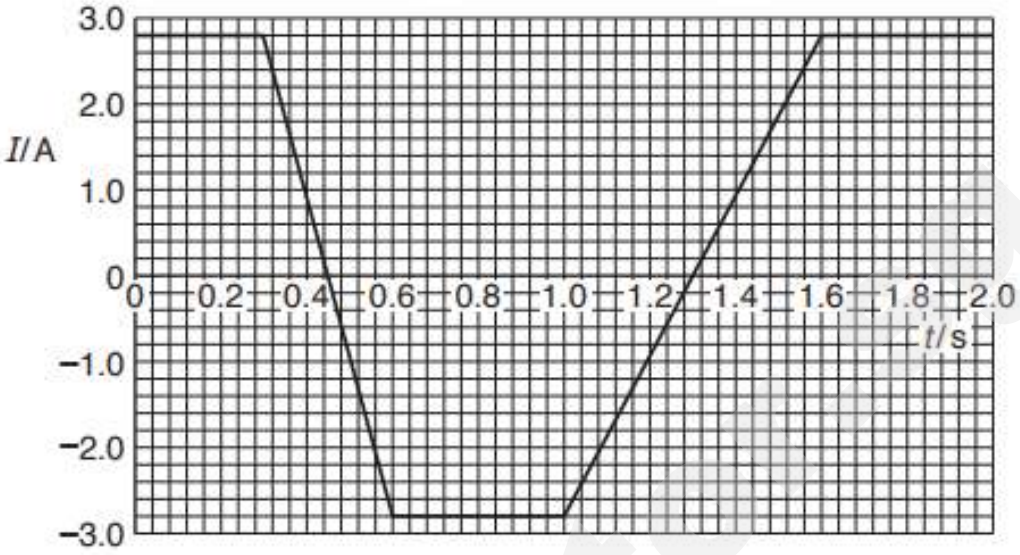

Fig. 5.2

Use your answer to **(b)(ii)** to show, on Fig. 5.3, the variation with time t of the e.m.f. E induced in coil **C**. [3]

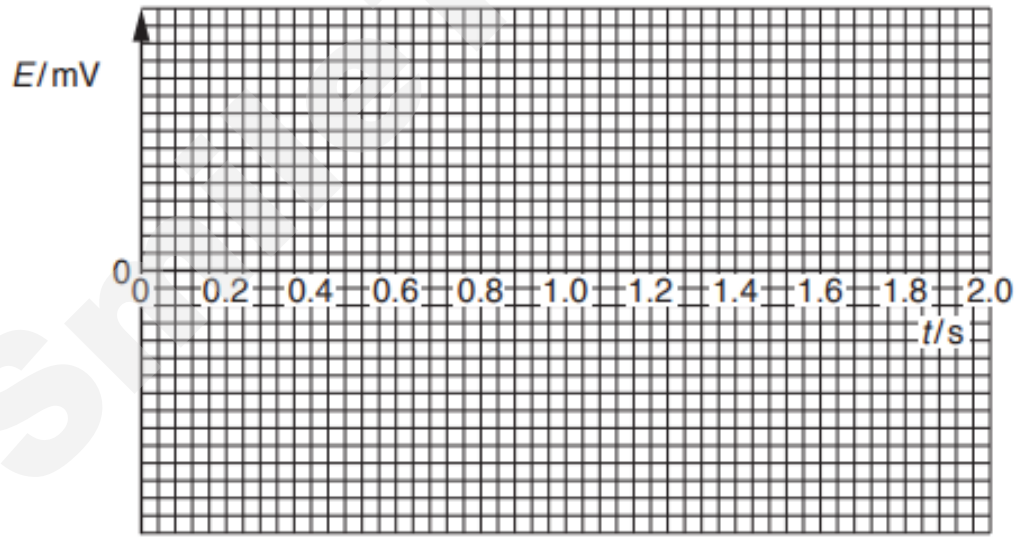

Fig. 5.3

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(iv) The current supplied to the solenoid is now replaced by an alternating voltage V given by the expression

$$V = 2.55 \sin (100\pi t)$$

Calculate the root-mean-square voltage of coil **C**, assuming that the setup behaves like an ideal transformer.

root-mean-square voltage = …… V [2]

(v) Explain why the assumption used in **(b)(iv)** is not valid.

……

……

…… [1]

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6 **(a)** Fig. 6.1 below shows three of the electron energy levels of mercury gas.

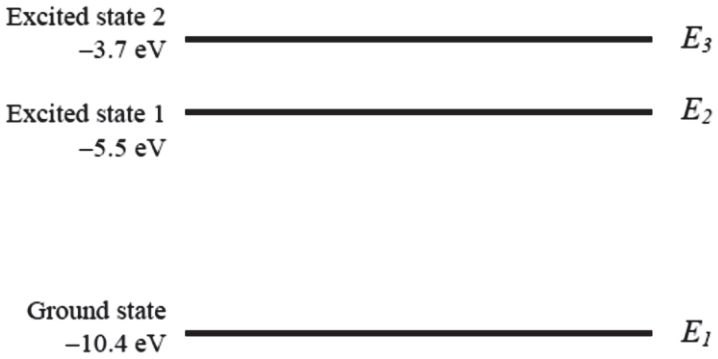

Fig. 6.1

When a current is passed through the gas at low pressure, a line spectrum is observed. Three of the lines which correspond to transitions between the energy levels are shown in Fig. 6.2.

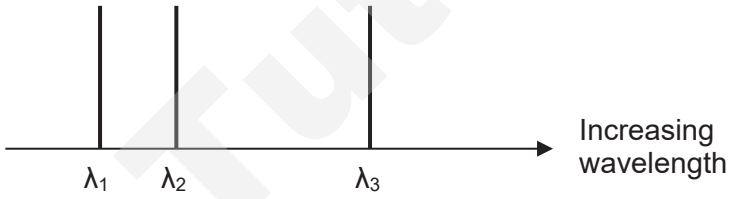

Fig. 6.2

(i) Determine the ionisation energy of mercury in J with respect to the electron in the ground state as given in Fig. 6.1.

ionisation energy = …….. J [1]

(ii) Identify the electronic transition responsible for the line spectrum of wavelength λ_3. Explain your answer.

……

……

…….. [2]

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(iii) Describe what happens to the atom in the ground state in order for the atom to emit light of wavelength λ_3.

.....

.....

.....

.....

..... [3]

(b) Fig. 6.3 below shows a setup used to investigate the photoelectric effect.

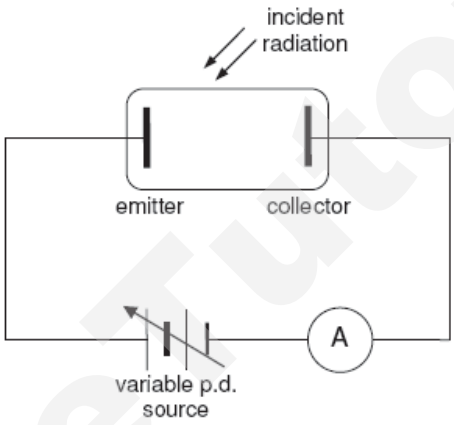

Fig. 6.3

When radiation of wavelength 225 nm is incident on the emitter, photoelectrons are emitted.

Fig. 6.4 below shows how the photocurrent I varies with the applied p.d. V between the emitter and the collector of the setup. The graph is obtained when the power of the radiation incident on the emitter is 2.85 mW.

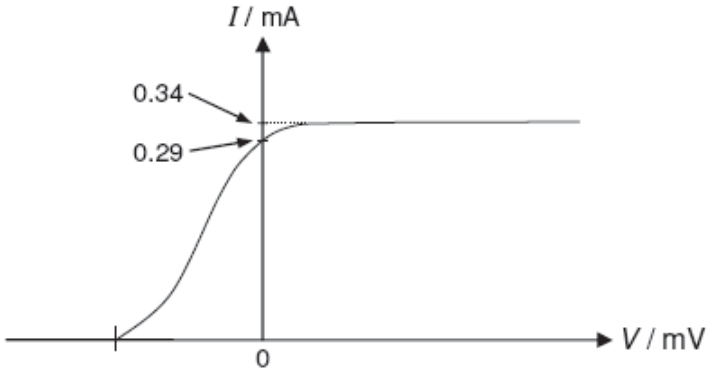

Fig. 6.4

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(i) Define *stopping potential*.

……

…….. [1]

(ii) A ratio, known as the *photoelectric quantum yield* is a measure of the efficiency of the photoelectric effect.

Photoelectric quantum yield is defined as

$$\frac{\text{no. of photoelectrons emitted per second}}{\text{no. of incident photons per second}}$$

Calculate the *photoelectric quantum yield* for this given experiment.

photoelectric quantum yield = …….. [3]

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7 The article below is based on an article on the Internet.

Read the article and then answer the questions that follow.

Photovoltaic (PV) Efficiency: The Temperature Effect

A photovoltaic (PV) cell absorbs light energy and converts this into electrical energy. A PV panel consists of a large number of photovoltaic cells. A PV system consists of a PV panel and the rest of the circuit to which it is connected.

Temperature generally affects current in an electrical circuit by changing the speed at which the electrons travel. In metals, this is due to an increase in resistance of the circuit that results from an increase in temperature. The opposite effect is seen in semiconductor materials where an increased temperature results in a decrease in resistance due to a change in the number density of charge carriers.

It is important that the equipment associated with a PV panel is appropriate for the context in which it will be used. The current and voltage output of a PV cell is affected by changing weather conditions. A PV system at a higher temperature will have a lower maximum voltage, lower efficiency and lower power output than the same system at a lower temperature.

Engineers must carefully choose the PV system for different temperature environments to ensure that the output voltage is not too high, which could damage the equipment. It is also important to consider the average operating voltage and current of a PV system for safety concerns, equipment capabilities and choices, and to minimise the amount of wire required for construction.

Since PV panels are more efficient at lower temperatures, engineers design systems with active and passive cooling. An example of active cooling is to pump water behind the panels to remove the heat. An example of passive cooling is to let the system be cooled by convection currents in the air.

While it is important to know the temperature of a solar PV panel to predict its power output, it is also important to know the PV panel materials because the efficiencies of different materials have varied levels of dependence on temperature. Therefore, a PV system must be engineered not only accordingly to the maximum, minimum and average environmental temperatures at each location, but also with an understanding of the materials used.

The temperature dependence of a material is described with a temperature coefficient. For monocrystalline PV panels, if the temperature decreases by 1 °C, the voltage increases by 0.48 V, so the temperature coefficient is 0.48 V $°C^{-1}$. The general equation for estimating the open circuit voltage V of a material at the temperature T of the panel is

$$V = \mu(T_R - T) + V_R$$

where μ is the temperature coefficient, T_R is a reference temperature and V_R is the open circuit voltage at the reference temperature. The temperatures are in degrees Celsius.

The variation with voltage of current at two different temperatures for one cell of the panel is shown in Fig. 7.1.

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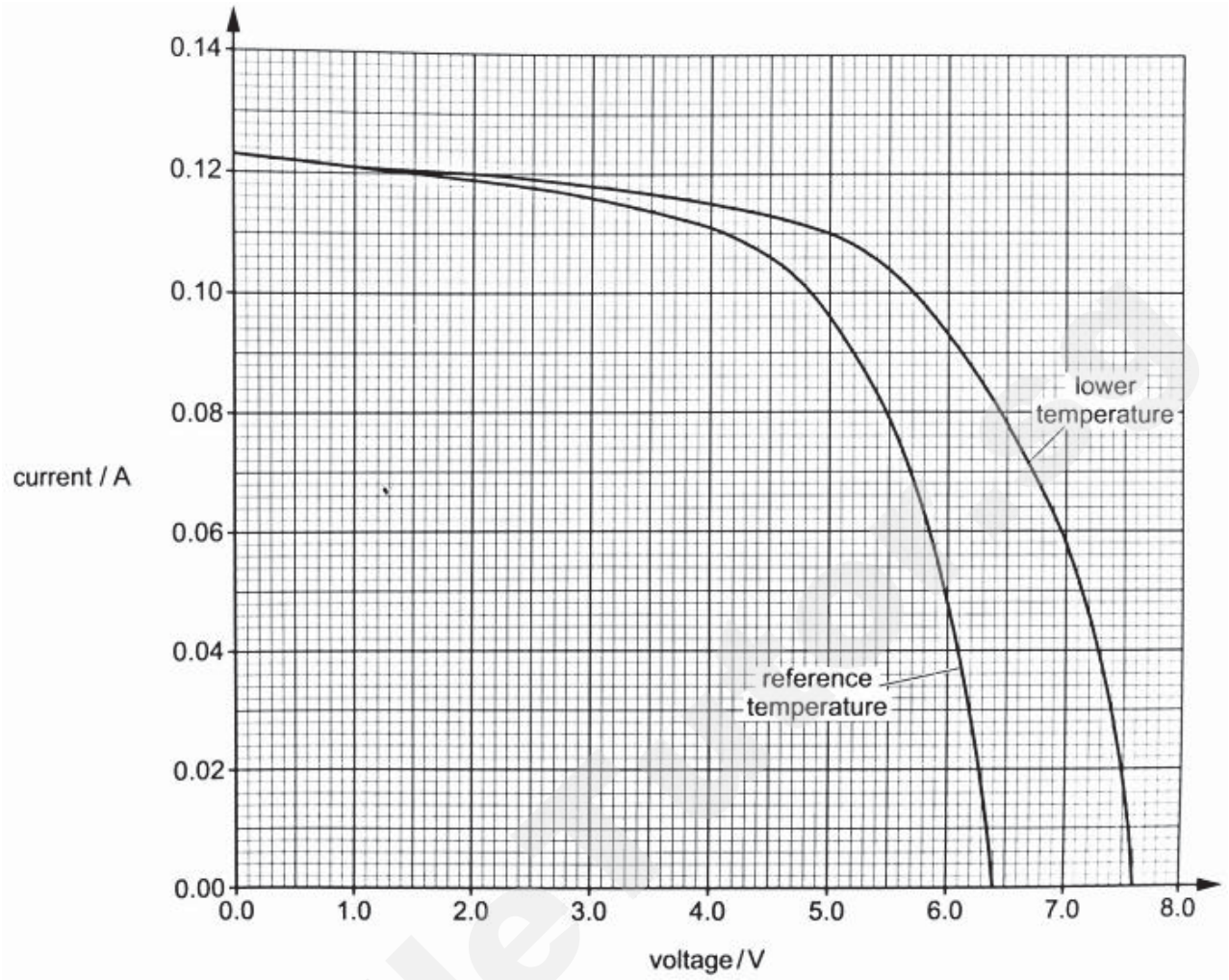

Fig. 7.1

(a) State and explain why the resistance of metals increases with temperature.

……

……

…… [2]

(b) The panel produces a much larger voltage or current than an individual cell. State how the cells are connected in a panel such that

(i) the voltage is increased,

…… [1]

(ii) the current is increased.

…… [1]

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(c) **(i)** Suggest what is meant by *passive cooling*.

……

……

…… [1]

(ii) Suggest why engineers do not design systems with active cooling alone.

……

……

…… [1]

(d) Suggest how passive air cooling may be enhanced for a PV panel.

……

……

…… [1]

(e) **(i)** Use Fig. 7.1 to state the open circuit voltage (e.m.f.) of the PV cell at both the reference temperature and the lower temperature.

V_R = …… V

V = ……V

[1]

(ii) Use Fig. 7.1 to describe qualitatively the variation with temperature of the current in the cell.

……

……

……

……

…… [2]

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(iii) Fig. 7.2 shows the variation with temperature T of the open circuit V. Draw the line of best fit. [1]

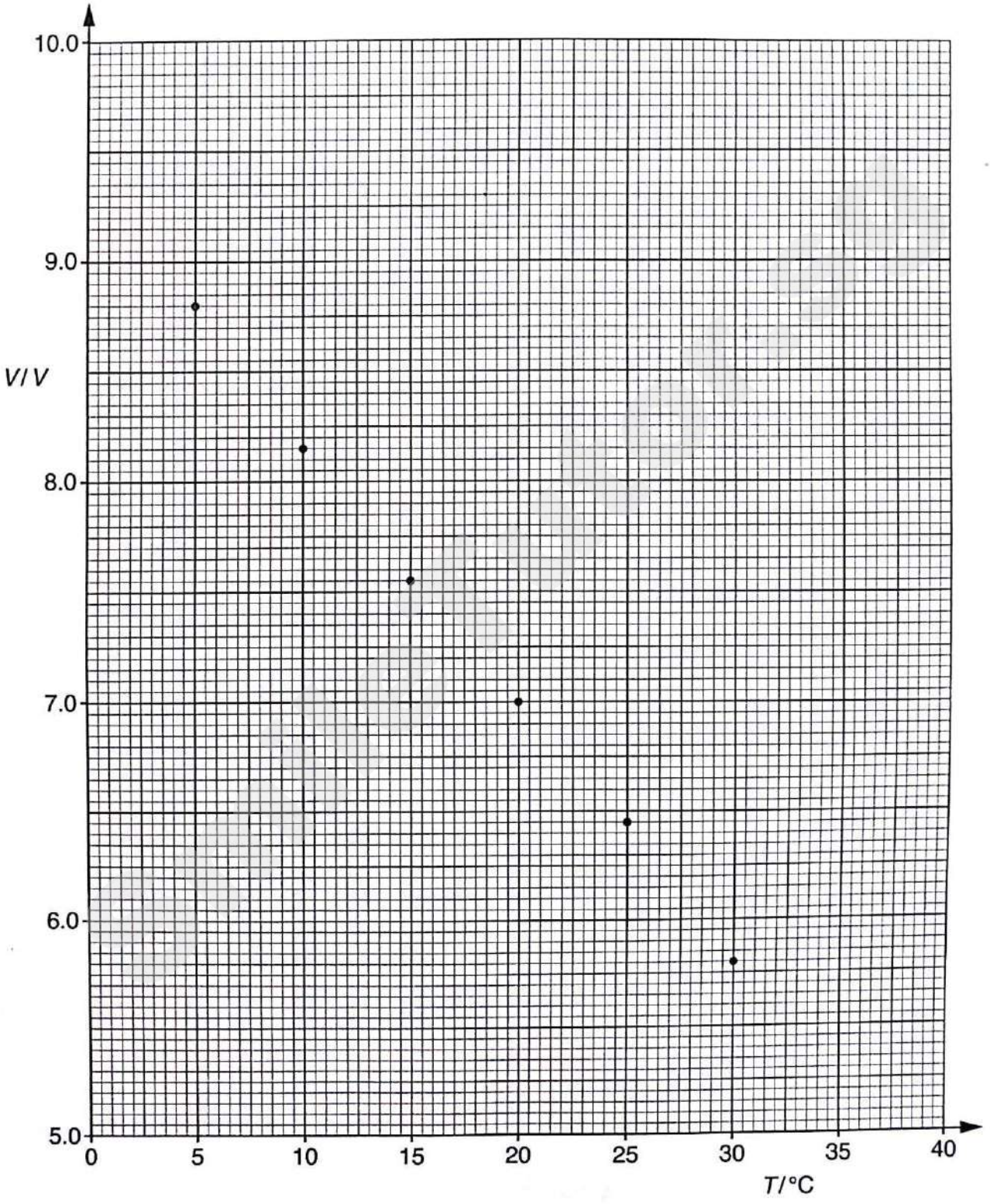

Fig. 7.2

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(iv) Use Fig. 7.2 to determine the constants μ and T_R.

μ = ... V °C^{-1}

T_R = ... °C

[3]

(v) Use your answers to **(e)(i)** and **(e)(iv)** to determine the lower temperature used to obtain the data for Fig. 7.1.

lower temperature = ... °C [1]

(vi) The PV cell is producing 6.0 V at the reference temperature.

On Fig. 7.1, indicate the area which represents the output power of the cell. [2]

(vii) Use Fig. 7.1, to estimate the maximum power output of the PV cell at the reference temperature.

maximum power output = ... W [2]

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(f) **(i)** A PV cell may have multiple layers of different semi-conducting materials. As the number of layers increases, the efficiency of conversion of light energy to electrical energy increases.

Suggest a reason why the efficiency increases.

……

……

…… [1]

(ii) Suggest how the angle between the PV panel and the incident sunlight affects the power output of the PV panel.

……

…… [1]

End of paper

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Class	Index Number	Name
16S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2017
Preliminary Examination

PHYSICS, Higher 2 **9749/03**

Paper 3 Longer Structured Questions **18th September 2017**
2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid..

The use of an approved scientific calculator is expected, where appropriate.

Section **A**
Answer **all** questions.

Section **B**
Answer any **one** question

You are advised to spend about one hour on each Section.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/ 10
2	/ 10
3	/ 10
4	/ 10
5	/ 20
Section B	
6	/ 20
7	/ 20
Total	/ 80

This document consists of **23** printed pages including this page.

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Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1}
		$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on/by a gas,	W	$= p\Delta V$
hydrostatic pressure,	p	$= \rho g h$
gravitational potential,	ϕ	$= -\frac{Gm}{r}$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_0 \cos \omega t$
	v	$= \pm \omega \sqrt{x_0^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas,	E	$= \frac{3}{2}kT$
resistors in series,	R	$= R_1 + R_2 + ...$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + ...$
electric potential,	V	$= \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	$= x_o \sin \omega t$
transmission coefficient,	T	$\alpha \exp(-2kd)$
	where k =	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{1/2}}$

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Section A

Answer **all** questions in the spaces provided.

1 A fixed mass of an ideal gas undergoes a cycle **ABCA** of changes, as shown in Fig. 1.1.

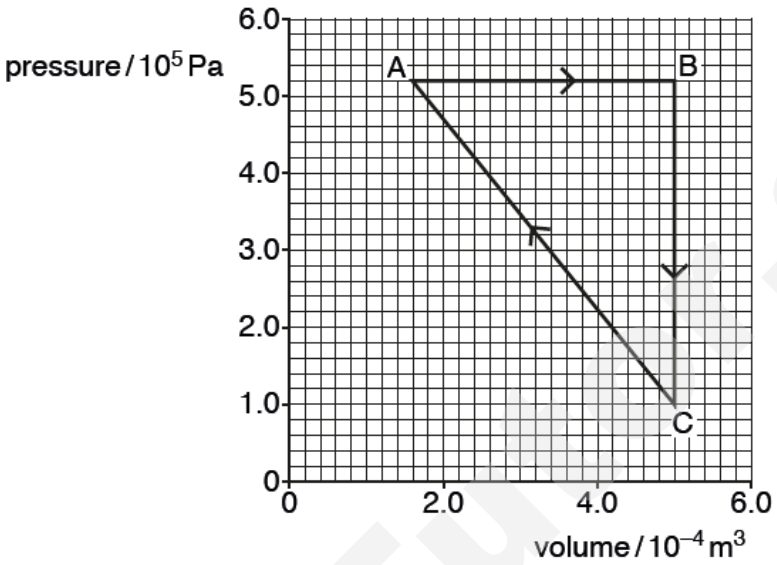

Fig. 1.1

(a) During the change from **A** to **B**, the energy supplied to the gas by heating is 442 J. Use the first law of thermodynamics to calculate the change in internal energy of the gas.

change in internal energy = …….. J [2]

(b) During the change from **B** to **C**, the internal energy of the gas decreases by 313 J.

By considering molecular energy, state and explain qualitatively the change, if any, in the temperature of the gas.

……

……

……

…… [2]

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(c) For the change from **C** to **A**, calculate the energy supplied to the gas by heating.

energy supplied by heating = …….. J [2]

(d) The temperature of the gas at point **A** is 227 °C. Calculate the number of molecules in the fixed mass of the gas.

number of molecules = …….. [2]

(e) Calculate the root-mean-square speed of the gas molecules at point **B** if the root-mean-square speed at point **A** is 350 m s^{-1}.

root-mean-square speed = …….. m s^{-1} [2]

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2 **(a)** Noise cancelling headphones, as shown in Fig. 2.1 below, were first invented to cancel the noise in aeroplane and helicopter cockpits. They work using the principle of superposition of waves.



Fig. 2.1

Sound waves enter and pass through the headphone and are detected by a microphone. An electric circuit sends a signal to the loudspeaker so that it produces an 'opposite wave', as shown in Fig. 2.2.

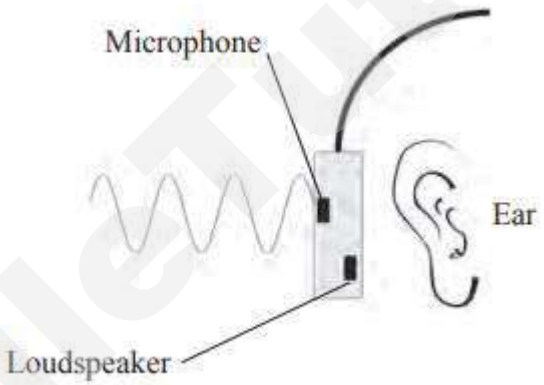

Fig. 2.2

(i) State the conditions necessary to produce complete cancellation of the two waves that reach the ear drum.

……

……

……

……

…… [3]

(ii) In practice, noise-cancelling headphones are more effective in cancelling noise from a jet engine rather than from a speech or music. Suggest a reason for this.

……

…… [1]

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(b) Explain the term *diffraction*.

……

…… [1]

(c) A diffraction grating has slits of separation d. The grating is capable of producing only up to the third order maxima when illuminated normally by light of wavelength λ.

Determine the range of possible values of d in terms of λ.

range of d is …… [2]

(d) When one receives a chest x-ray in a hospital, the x-rays pass through a series of parallel ribs in the chest. Suggest why the ribs do not produce an interference and diffraction pattern like a diffraction grating.

.....

..... [1]

(e) Two point sources of light are placed 12 mm apart and emit light of wavelength 0.60 μm.

Calculate the maximum distance at which the two sources can just be distinguished by an observer with an eye pupil diameter of 4.0 mm.

maximum distance = …… m [2]

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3 **(a)** A student attempts to measure the resistivity of soil using two parallel copper plates driven into the ground as shown in Fig. 3.1.

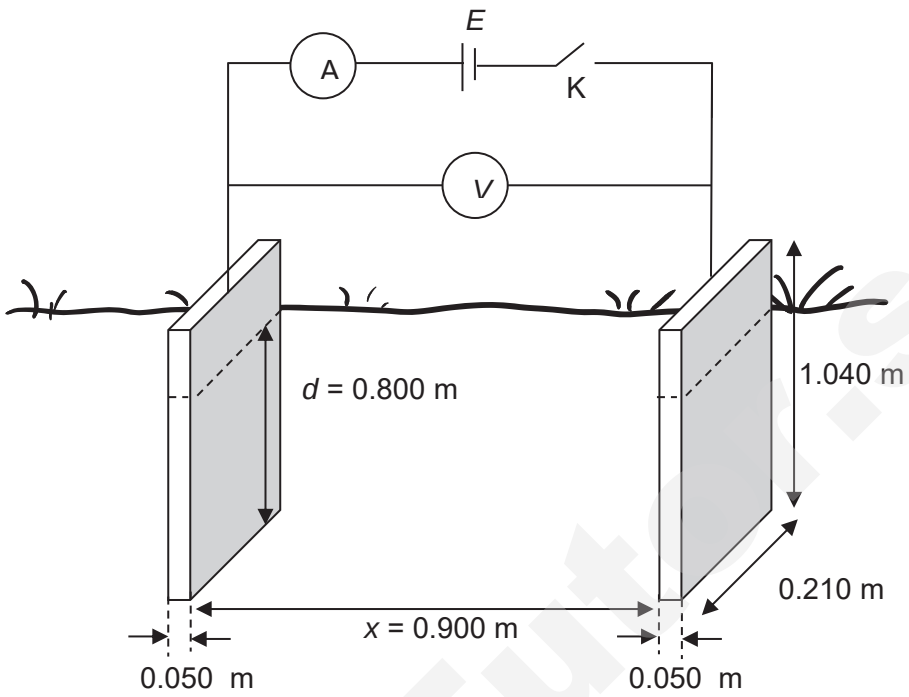

Fig. 3.1

Each copper plate has a height of 1.040 m, a width of 0.210 m and a thickness of 0.050 m. Assume that the ammeter has zero resistance and the voltmeter has infinite resistance.

The copper plates are driven to a depth d of 0.800 m and separated by a distance x = 0.900 m. When switch K is closed, the student obtained a voltmeter reading of 1.398 V and an ammeter reading of 0.31 mA.

(i) Determine the resistance of the soil between the copper electrodes.

resistance = ... Ω [2]

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(ii) Hence, calculate the resistivity of the soil.

resistivity = …… [2]

(b) Explain what is meant by the statements:

(i) A battery has an electromotive force (e.m.f.) of 3 V.

……...

……...

…….. [1]

(ii) The potential difference across a resistor is 2 V.

……...

……...

…….. [1]

(c) A cell of negligible internal resistance is connected in series with a microammeter of negligible resistance and two resistors whose resistances are 10 kΩ and 15 kΩ. The current is 200 μA.

(i) Calculate the e.m.f. of the cell.

emf = ……V [1]

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(ii) When a voltmeter is connected in parallel with the 15 kΩ resistor, the current in the microammeter increases to 250 μA.

Calculate the resistance of the voltmeter.

resistance = ……Ω [3]

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4 **(a)** State what is meant by a magnetic field.

……

…… [1]

(b) A particle of charge +q and mass m is travelling in a vacuum with speed v. The particle enters a uniform magnetic field of flux density B at 90°, as shown in Fig. 4.1.

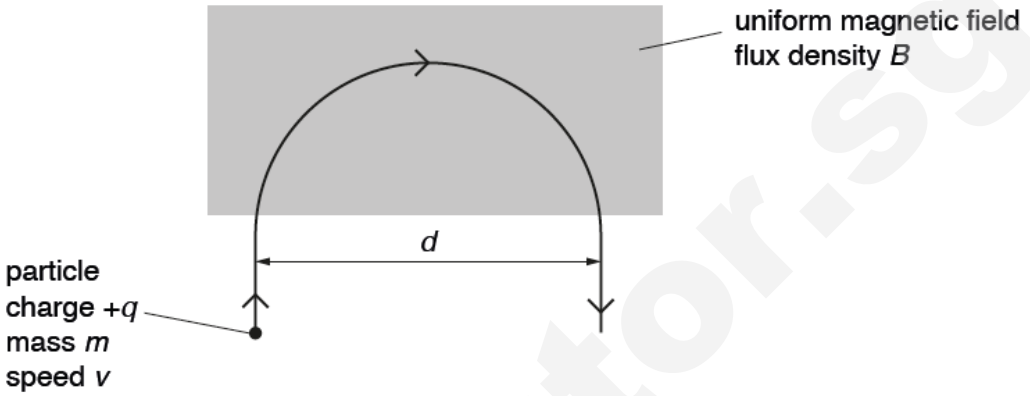

Fig. 4.1

The particle leaves the field after following a semi-circular path of diameter d.

(i) State the direction of the magnetic field

…… [1]

(ii) Explain why the kinetic energy of the particle is not affected by the magnetic field.

……

……

…… [2]

(iii) Show that the diameter d of the semi-circular path is given by the expression

$$d = \frac{2mv}{Bq}$$

[2]

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(iv) Show that the time T spent in the field by the particle is independent of its speed v. [2]

(v) The positively-charged particle disintegrates into 2 oppositely charged particles in a direction which has a component perpendicular to the plane of the paper.

Describe the path of the negatively-charged particle going out of the plane of the paper.

……...

……. [1]

(vi) Suppose the positively-charged particle did not disintegrate.

Draw on Fig. 4.1 the direction of an electric field that can be applied so that the charged particle travels in a straight line through the magnetic field.

[1]

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5 **(a)** An α-particle **A** approaches and passes by a stationary gold nucleus **N**. The path is illustrated in Fig. 5.1.

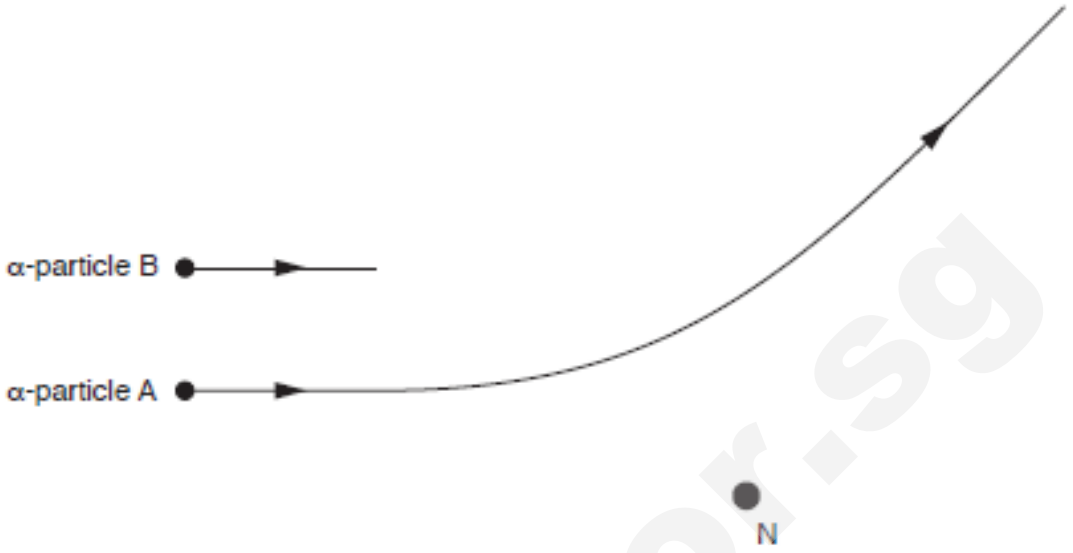

Fig. 5.1

(i) A second α-particle **B** has the same initial direction and energy as α-particle **A**.

On Fig. 5.1, complete the path of α-particle **B** as it approaches and passes nucleus **N**. [1]

(ii) State what can be inferred about atoms from the observations that very few α-particles experience large deviations.

……

…… [1]

(iii) The nucleus **N** could be one of several different isotopes of gold.

Suggest, with an explanation, whether different isotopes of gold would give rise to different deviations of a particular α-particle.

……

……

…… [2]

(iv) The α-particles in this experiment originated from the decay of a radioactive nuclide. Suggest why β-particles from a radioactive source would be inappropriate for this type of scattering experiment.

……

…… [1]

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(b) When a neutron is captured by a uranium-235 nucleus, the outcome may be represented by the nuclear equation shown below.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{95}_{42}\mathrm{Mo} + ^{139}_{57}\mathrm{La} + x\,^{1}_{0}\mathrm{n} + 7\,^{0}_{-1}\mathrm{e}$$

Some data for the nuclei in the reaction are given in Fig. 5.2.

	mass/u	binding energy per nucleon /MeV
uranium-235 ($^{235}_{92}$U)	235.123	
molybdenum-95 ($^{95}_{42}$Mo)	94.945	8.09
lanthanum-139 ($^{139}_{57}$La)	138.955	7.92
proton ($^{1}_{1}$p)	1.007	
neutron ($^{1}_{0}$n)	1.009	

Fig. 5.2

(i) Determine the value of x.

x = ... [1]

(ii) Show that the binding energy per nucleon of a nucleus of uranium-235 is 7.18 MeV.

[3]

(iii) In Fig. 5.2, the binding energy *per nucleon* of molybdenum-95 is stated as 8.09 MeV.

Explain what is meant by this statement.

.....

..... [1]

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(iv) The kinetic energy of the neutron before the reaction is 10.0 MeV. Calculate the total energy released in this reaction.

energy released = …… MeV [2]

(c) The curie (Ci) is a non-SI unit of radioactivity named in honour of the pioneers of radioactivity research, Pierre Curie and Marie Curie. It was taken to be the activity of 1.0 g of isotope radium-226 which has a half-life of 1600 years.

(i) Show that 1 Ci = 3.7×10^{10} Bq. [2]

(ii) Given that the Solar System is about 5×10^{9} years old, suggest why radioactive nuclei of radium-226 can still be found in nature.

……

…… [1]

(d) **(i)** State what is meant by the *decay constant* of a radioactive isotope.

……

…… [1]

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(ii) In order to determine the half-life of a sample of a radioactive isotope, a student measures the count rate near the sample, as illustrated in Fig. 5.3.

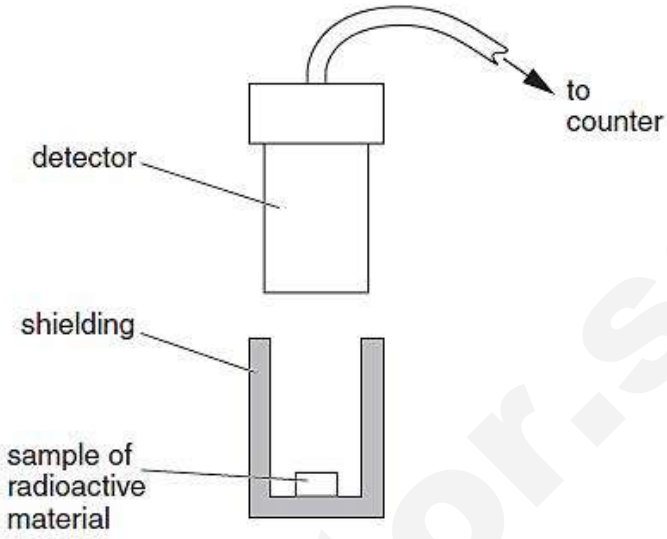

Fig. 5.3

Initially, the measured count rate is 538 per minute. After a time of 8.0 hours, the measured count rate is 228 per minute.

Use these data to estimate the half-life of the isotope.

half-life = …… hours [2]

(iii) The accepted value of the half-life of the isotope in **(d)(ii)** is 5.8 hours. The difference between this value for the half-life and that calculated in **(d)(ii)** cannot be explained by reference to faulty equipment.

Suggest two possible reasons for this difference.

1. ……

……

2. ……

…… [2]

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Section B

Answer **one** question from this Section in the spaces provided.

6 **(a)** Fig. 6.1 below shows an M777 howitzer firing a projectile at an angle of 50° to the horizontal. The projectile exits the muzzle at a speed of 800 m s^{-1}.

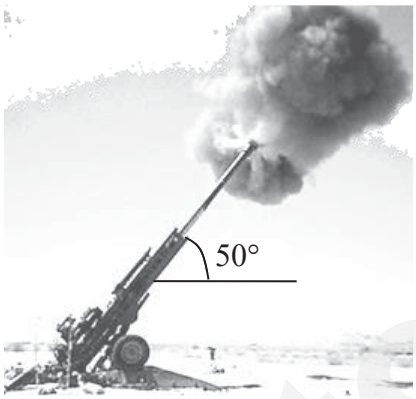

Fig. 6.1

(i) Neglecting air resistance and the height of the howitzer, determine the range of this projectile, *d*, for the angle given.

d = …… km [3]

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(ii) It can be proven that launching the projectile at 40° will achieve the same range.

Suggest one advantage of launching the projectile at this smaller angle.

……

…… [1]

(b) A howitzer is set up to destroy enemy tank by aiming its projectile to land at the expected position of the moving tank.

The enemy tank, initially stationary, is 3.0 km away from the landing point of the howitzer's projectile as shown in Fig. 6.2 below.

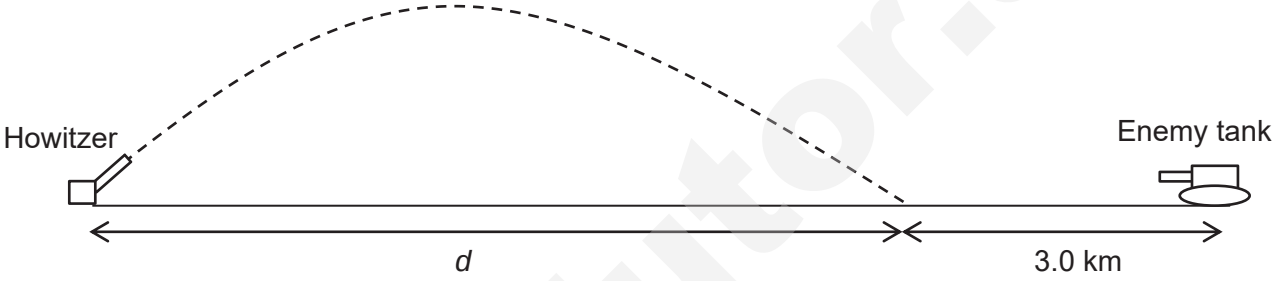

Fig. 6.2

The tank has a maximum speed of 60 km h^{-1} and a maximum acceleration of 1.0 m s^{-2}.

(i) Calculate the minimum time required for the tank to reach the landing point of the howitzer's projectile.

time = …… s [4]

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(ii) Calculate how long after the tank starts moving should the howitzer start firing so that the projectile will hit the tank.

time = …… s [1]

(c) In reality, the projectile experiences a large magnitude of air resistance that limits its maximum range.

(i) In Fig. 6.3(a) and 6.3(b), draw and label the forces acting on the projectile as it is moving up and as it is moving down. [2]

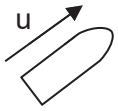

Fig. 6.3(a) Projectile moving up



Fig. 6.3(b) Projectile moving down

(ii) Draw a labelled graph on Fig. 6.4 below to show the variation with time of the vertical velocity of the projectile. Take downward as positive.

Indicate on the x-axis the time to reach maximum height t_m and time to reach the ground again t_g.

[3]

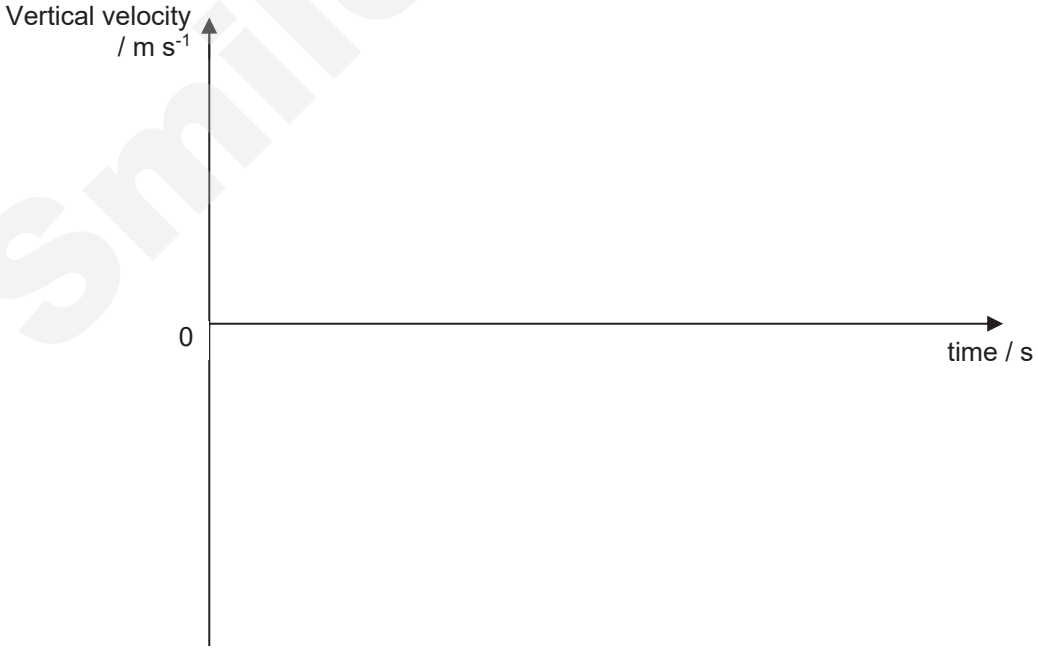

Fig. 6.4

(iii) On the same Fig. 6.4**,** draw a graph to show the variation with time of the vertical velocity of the projectile *without air resistance*. Label this graph N. [2]

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(iv) Explain whether you would expect the time taken for the projectile to reach its maximum height to be longer or shorter than the time taken for it to land from its maximum height in the presence of air resistance.

……

……

……

…… [2]

(d) If the howitzer and the projectile are considered as a system, explain whether the principle of conservation of momentum could be applied to this system during the firing process.

……

……

…… [2]

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7 **(a)** Define the following terms,

(i) angular velocity, and

……...

…… [1]

(ii) the radian.

……...

…… [1]

(b) At the Marina Bay Street Circuit which is the track for the 2017 Formula One Singapore Grand Prix held yesterday, the slowest part of the circuit is at **Turn 8** where the race car drivers make a sharp turn in front of the Stamford Grandstand, as shown in Fig 7.1.

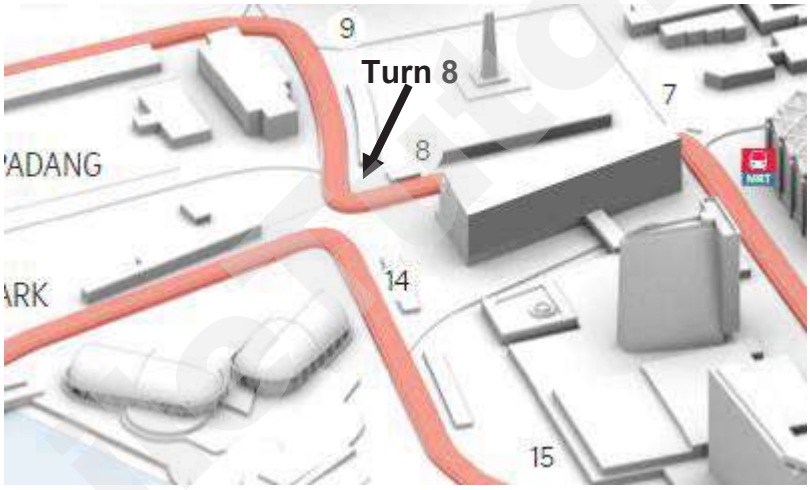

Fig. 7.1

Assuming that the slowest point of **Turn 8** is part of a *circular road* of radius 19.0 m, and a race car (with driver, fuel and equipment all included) has a mass of 900 kg and it moves at a speed of 68.0 km h^{-1} at that slowest point,

(i) determine the resultant force acting on the vehicle at that point.

resultant force = …….. N [3]

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(ii) State the force acting on the vehicle that provides for this resultant force.

…… [1]

(iii) Explain why a banked turn (with the road inclined at an angle), as shown in Fig. 7.2 below, can assist the Formula One car to maneuver that turn at a higher speed.

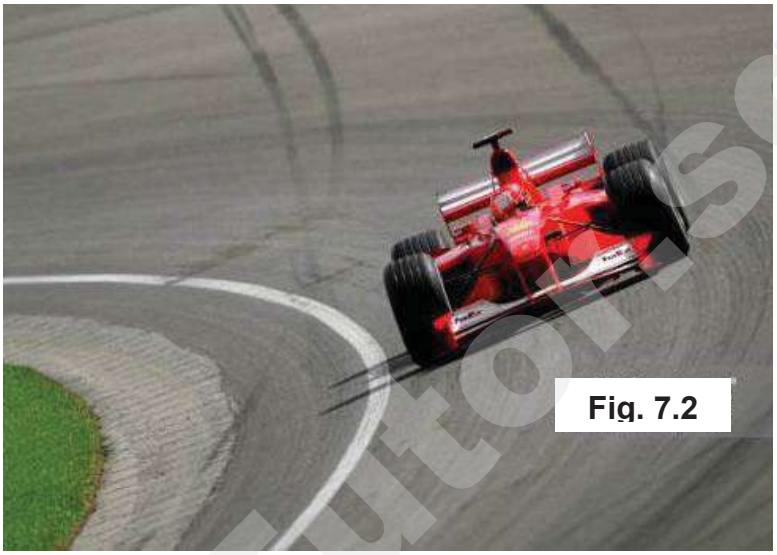

Fig. 7.2

……

……

…… [2]

(c) Artificial satellites are used to monitor weather conditions on Earth, for surveillance and for communications. Such satellites may be placed in a *geo-synchronous* (geostationary) orbit or in a low polar orbit.

Describe the properties of the geo-synchronous orbit and the advantages it offers when such a satellite is used for communications.

……

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……

……

……

…… [3]

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(d) A satellite of mass 2.5 x 10^3 kg is to be moved from the surface of the Earth to an orbit of radius 1.6 x 10^7 m around the Earth. The mass of the Earth is 6.0 x 10^{24} kg.

(i) Calculate the gravitational force acting on the satellite when in orbit.

gravitational force = …… N [2]

(ii) Given that the gravitational potential at the surface of the Earth (due to the Earth) is – 63 MJ kg^{-1}, calculate the increase in the gravitational potential energy (GPE) of the satellite when it is placed in the orbit.

increase in GPE = ……J [3]

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(e) One of the moons of Jupiter, Ganymede, is the largest satellite in the solar system. Its orbital period is equal to 7.15 Earth days and the radius of its orbit is 1.07×10^9 m.

Calculate the mass of Jupiter.

mass = ……kg [4]

End of paper

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Civics Group	Index Number	Name
16S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2017
Preliminary Examination

PHYSICS

9749/04

Paper 4 Practical

23rd August 2017 **2 hours 30 minutes**

Candidates answer on the Question Paper.

Additional Materials: As listed on the Confidential Instructions.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.
Give details of the practical shift and laboratory where appropriate in the boxes provided.

Shift
Laboratory

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
Total	/50

This question paper consists of 16 printed pages including this page.

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1 In this experiment, you will alter the positions of two extended springs and measure how the coiled length of one of the springs varies with the angle between the springs.

Two springs, supporting a mass hanger and masses, are resting on a blade. You will alter the separation of the springs and measure the coiled length of one of the springs.

Take care when moving the springs along the sharp edge of the blade.

(a) Gently remove the mass hanger and masses leaving the springs on the blade. Measure the unextended length L_0 of the **right-handed** spring using the rule as shown in Fig. 1.1. Record L_0.

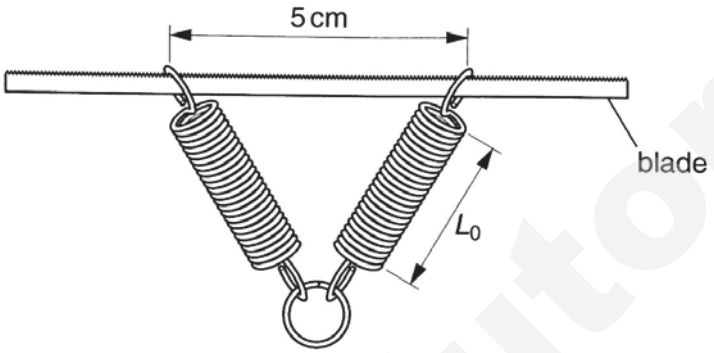

Fig. 1.1

L_0 = ...[1]

(b) Set the separation of the tops of the springs to 25 cm. Carefully replace the mass hanger and masses, as shown in Fig. 1.2.

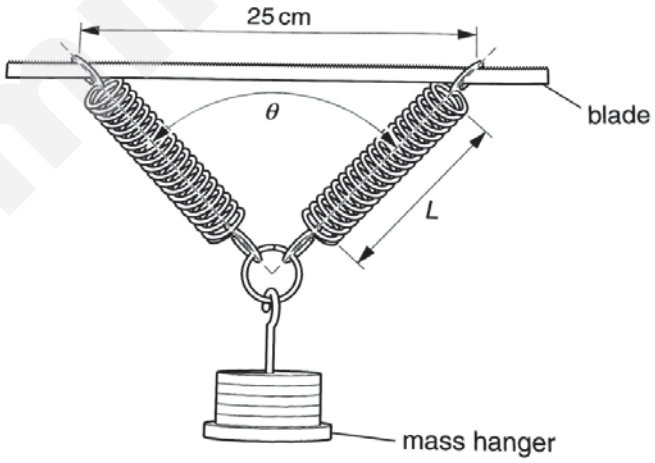

Fig. 1.2

(i) Measure and record the angle θ between the springs.

θ = ...

(ii) Measure and record the length L of the **right-handed** spring.

L = ...

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(c) Change the separation of the springs to vary θ in the range $30^0 < \theta < 80^0$ and repeat steps **(b)(i)** and **(b)(ii)** until you have five sets of readings of θ and L.

Include values of $\frac{1}{\cos(\theta/2)}$ in your table.

[7]

(d) Suggest a reason why the minimum value of θ was restricted to 30^0.

……

……

……[1]

(e) **(i)** Plot a graph of $\frac{1}{\cos(\theta/2)}$ against L. Draw the line of best fit.

(ii) Determine the gradient of the line.

gradient = ……[1]

(iii) Determine the y-intercept of the line.

y-intercept = ……[1]

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graph paper 3 marks

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(f) θ and L are related by the expression

$$\frac{1}{\cos(\theta/2)} = P\,L - Q$$

where P and Q are constants.

Use values from **(e)(ii)** and **(e)(iii)** to determine a value for Q/P.

Q/P = ……[2]

(g) State two major sources of error in this experiment.

1. ……..

……

……

2. ……..

……..

……[2]

[Total: 18 marks including 3 for graph work]

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2 In this experiment you will investigate an oscillating system.

(a) **(i)** Put the ball of modelling clay on the bench. Press the board on the ball to flatten it and form the modelling clay into a cylinder as shown in Fig. 2.1. Work with a value of *d* between about 4 cm and 5 cm.

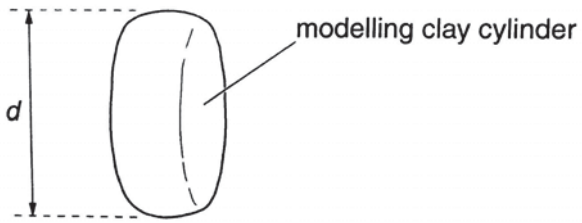

Fig. 2.1

(ii) Measure and record the diameter *d* of the cylinder using the vernier caliper.

d = ...[1]

(iii) Determine the percentage uncertainty in your value of *d*.

percentage uncertainty in *d* = ...[1]

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(b) **(i)** Push the nail through the cylinder near the edge to produce a hole, as shown in Fig. 2.2.

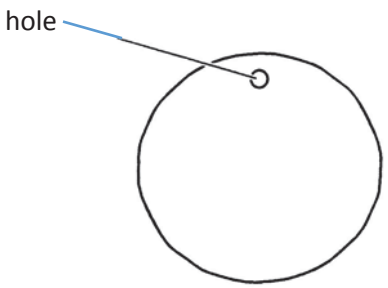

Fig. 2.2

(ii) With the nail in the hole, hold the cylinder and gently lift the nail so that it opens up a gap in the cylinder as shown in Fig. 2.3. You may have to push the nail a little to open up a gap. Ignore any remnant of clay that remains stuck to the nail.

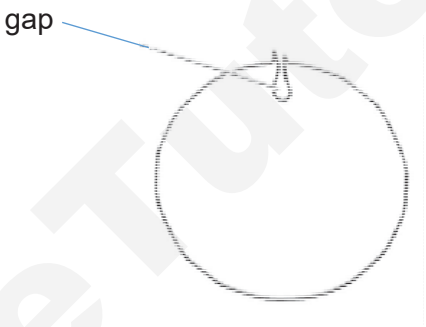

Fig. 2.3

(iii) Insert the rubber band into the gap in the cylinder. Close the gap by pushing the modelling clay together. Use Sellotape to tape over the region to prevent the rubber band from opening up a gap. The rubber band should be positioned in the cylinder as shown in Fig. 2.4.

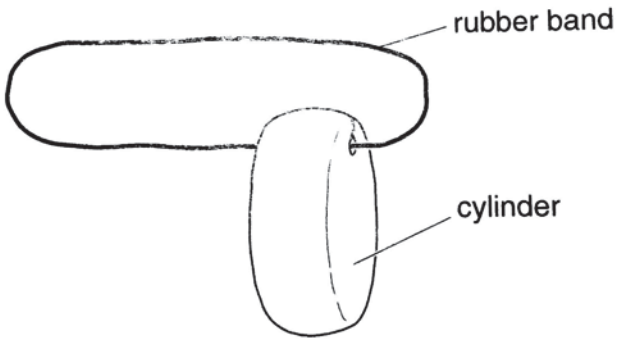

Fig . 2.4

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(c) **(i)** Place the rubber band on the end of the rod of the clamp to arrange the apparatus as shown in Fig. 2.5.

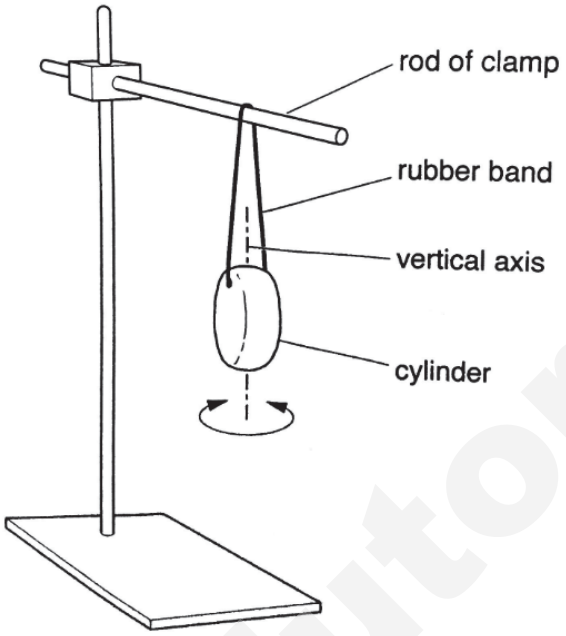

Fig. 2.5

(ii) Rotate the cylinder through approximately 90^0 about the vertical axis as shown in Fig.2.5. Release the cylinder and allow it to oscillate.

Determine the period *T* of these oscillations.

T = ...[1]

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(d) **(i)** Remove the rubber band from the cylinder.

(ii) Flatten the cylinder further between the board and the bench so that the value of d is at least 6 cm.

(iii) Repeat **(a)(ii), (b)** and **(c).**

d = ……..[1]

T = ……..[1]

(e) It is suggested that T and d are related by the expression

$$T^2 = k\, d^3$$

where k is a constant.

(i) Use your values from **(a)(ii)**, **(c)(ii)** and **(d)(iii)** to determine two values of k.

first value of k = ……

second value of k = ……..[1]

(ii) State whether or not the results of your experiment support the suggested relationship.

Justify your conclusion**.**

……..

……..

……..

……..

……..…[1]

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(f) **(i)** Suggest **two** significant sources of error in this experiment.

1……..

……..

……

2……..

……..

……[2]

(ii) Suggest **two** improvements that could be made to the experiment to address the errors identified in **(f)(i)**. You may suggest the use of other apparatus or a different procedure.

1……..

……..

……

2……..

……..

……[2]

[**Total: 11 marks**]

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3 In this experiment, you will determine the resistance of a voltmeter and of an unknown resistor.

You are provided with two resistors of approximately equal resistances R_1 and R_2. You are also provided with a cell, a voltmeter, an ammeter and sufficient connecting wires.

(a) Connect the circuit of Fig. 3.1.

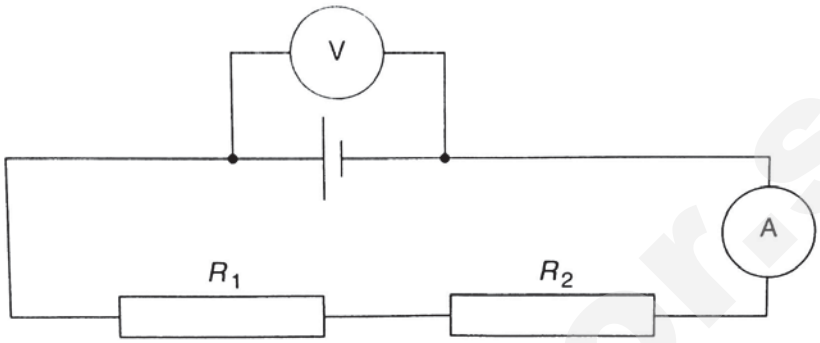

Fig. 3.1

(b) Record the voltmeter reading V_0 and the ammeter reading I_0.

V_0 = ……..…..… I_0 = ……..[1]

(c) **(i)** Disconnect the voltmeter. Reconnect the voltmeter across the resistor of resistance R_1 only.

Measure and record the voltmeter reading V_1 and the ammeter reading I_1.

V_1 = ……..…..… I_1 = ……..

(ii) Again disconnect the voltmeter. Reconnect the voltmeter across the resistor of resistance R_2 only.

Measure and record the voltmeter reading V_2 and the ammeter reading I_2.

V_2 = ……..…..… I_2 = ……..……..…..[1]

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(d) For a series circuit, it is suggested that

$$V_0 = V_1 + V_2 \quad \textit{and} \quad I_0 = I_1 = I_2$$

Suggest why your results do not support these relationships.

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.....[2]

(e) **(i)** Connect the circuit of Fig. 3.2.

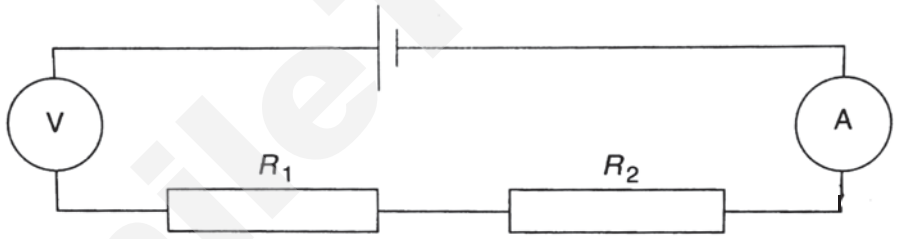

Fig. 3.2

(ii) Record the voltmeter reading V_3 and the ammeter reading I_3.

V_3 = ... I_3 = ...

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(iii) Use your readings to determine the resistance R_v of the voltmeter and the resistance R_1.

(You may find the following relationships useful:

$R = \frac{V}{I}$, resistors in series $R_{total} = R_1 + R_2$)

[2]

R_v = …….

R_1 = …….

(iv) Justify the number of significant figures in your value of R_1.

……

……

……

……

……[1]

(v) Suggest one change to the apparatus in the circuit of Fig. 3.1 to give a more accurate determination of R_1.

……

……

……[1]

[**Total: 8 marks**]

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4 Under normal conditions, air is a poor conductor of electricity. However, when the electric field in the air reaches a certain 'breakdown value', electrons are stripped or 'ionised' from the air molecules. The ionised air allows the sudden and massive flow of electric current. The enormous amount of heat associated with this current may cause a spark to be generated.

Design an experiment to investigate how the minimum voltage needed to generate a spark across a fixed gap of air varies with the temperature of the air.

You may assume that the following equipment is available, together with any other apparatus which may be found in an A-level science laboratory:

Transparent thermally-insulated chamber

High voltage power supply

Metal plate electrodes

You should draw a diagram to show the arrangement of your apparatus. In your account, you should pay particular attention to

(a) how the temperature of the air can be varied,

(b) the procedure to be followed,

(c) the control of variables, and

(d) any precautions that would be taken to improve the accuracy and safety of the experiment.

[**Total**: **13 marks**]

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Diagram

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End of Paper

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JC2 Preliminary Exam 2017 (H2 Physics)

Paper 1 Solutions

Qn	1	2	3	4	5	6	7	8	9	10
Ans	A	D	B	C	B	D	C	B	C	A

Qn	11	12	13	14	15	16	17	18	19	20
Ans	D	A	B	C	C	A	C	D	D	A

Qn	21	22	23	24	25	26	27	28	29	30
Ans	A	D	C	A	C	A	B	C	B	

Qn	Ans	Description
1	A	There are 9 oscillations counted by the student, whereas there are 10 oscillations in reality. Thus student's calculated period = 0.9 T, where T is the actual period. Percentage error in student's calculation = $\frac{0.9T-T}{T} \times 100\%$ = -10 % (hence 10% lower)
2	D	$B = \mu_o nI = \frac{F}{IL}$ $[\mu_o] = \left[\frac{F}{nI^2L}\right] = \frac{\text{kg m s}^{-2}}{\text{m}^{-1}\text{A}^2\text{m}} = \text{kg m s}^{-2}\text{A}^{-2}$
3	B	At max height, velocity of the projectile = horizontal component of initial velocity = v cos θ Therefore, KE at max height = ½ m(v cos θ)^2 = (½ mv^2)(cos^2 θ) = (cos^2 θ)(Initial KE)
4	C	Area under v-t graph is the displacement moved. Since total area is increasing from t = 0 to 2, and start to decrease from t = 2, hence answer is C.
5	B	F_L = Force exerted by the locomotive Considering the forces acting on the 6 trucks (take the 6 trucks to be one system), $F_L - 6(4000) = ma$, but a = 0 since it is constant speed. F_L = 24000 N When the coupling between trucks 2 and 3 snaps, considering only the forces acting on trucks 1 and 2 as a system, $F_L - 2(4000) = ma$ $F_L - 2(4000) = (2 \times 6.0 \times 10^4 + 24 \times 10^4)a$, where F_L = 24000 N Hence, a = 0.044 m s^{-2}
6	D	Taking the system as the boy and boat B, initial momentum = 0. Hence, when the boy jumps, taking leftward as positive, $mv_{boy} = Mv_B$

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		Now, taking the system as the boy and boat A, Initial momentum = mv_{boy} (since before contact, the boy is moving while the boat A is stationary) Hence, Final momentum = $(m+M)v_A = mv_{boy}$ $(m+M)v_A = Mv_B$ $v_A / v_B = M / (m+M)$
7	C	For a smooth surface there is no friction, hence, the force at that point acting on the cube must be perpendicular to the surface. Option C is the answer instead of A because friction acts towards S_2 as it prevents the object from slipping downwards. The combination of friction and reaction makes Q tilt towards S_2.
8	B	Since $m / t = \rho V / t = (1000)(1.4) = 1400$ kg s^{-1} Since efficiency = 20%, power output = $(0.2)(GPE / t)$ $= (0.2)(mgh) / t$ $= (0.2)(m / t)(gh)$ $= (0.2)(1400)(9.81)(750)$ $= 2.1$ MW
9	C	The gradient of the energy-time graph is the force, thus, the answer is C. Had this been a potential-time graph, the gradient would have been the field or acceleration.
10	A	$g = \frac{GM}{R^2} = \frac{G\rho V}{R^2} = \frac{G\rho\frac{4}{3}\pi R^3}{R^2} = \frac{4}{3}G\rho\pi R$, hence, g is proportional to R.
11	D	$p = \frac{1}{3}\frac{m}{V}\langle c^2 \rangle$ $1 \times 10^5 = 1/3(1.6/0.5)\langle c^2 \rangle$ $\sqrt{\langle C^2 \rangle} = 306$ ms^{-1}
12	A	$p = \frac{1}{3}\frac{m}{V}\langle c^2 \rangle$ $1 \times 10^5 = 1/3(1.6/0.5)\langle c^2 \rangle$ $\sqrt{\langle C^2 \rangle} = 306$ ms^{-1}
13	B	max V = wA, $w = 1/10 \times 10^{-3} = 2 \times 3.14 f$ f = 15.9 Hz.
14	C	
15	C	The time for 3 full waves = 13 ms, hence, the period is $\frac{0.013}{3}$ s. The frequency is $\frac{1}{\text{period}}$ = 230 Hz.
16	A	Drawing the next instance where the waveform is displaced to the left will show that the corresponding particles are in the corresponding upper or lower positions.

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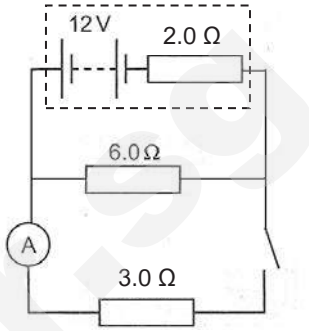
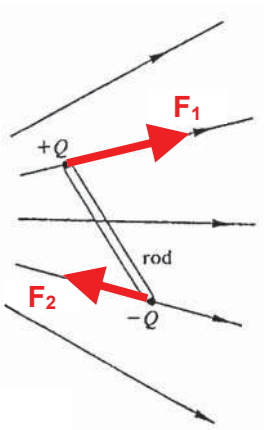
17	C	Total resistance in series with E_1 = 8.30 + 1.42 = 9.72 Ω. By pot divider principle, pd across whole pot wire XY = 8.30/9.72 x 9.00 = 7.69 V. At balance, emf E_2 = Pd across balance length *l* {no loss voltage across R} = 0.745/1.000 x 7.69 = 5.73 V.
18	D	The circuit can be redrawn in the following way. Let the total external resistance be *R*. Thus 1/R = 1/3 + 1/6 R = 2 Ω $E = I(R+r)$ where I = *total current* $12 = I(2.0 + 2.0)$ $I = 3.0$ A Ammeter reading = current through 3.0 Ω. Thus, ammeter reading = 6 / 9 x 3.0 A = 2.0 A 
19	D	For parallel plates, qE = ma qV/d = (9.11×10^{-31})a $(1.6 \times 10^{-19})(4500) / (1.5 \times 10^{-3})$ = (9.11×10^{-31})a a = 5.3×10^{17}
20	A	F_1 is larger than F_2 since the density of field at +Q is higher than at –Q. Hence, there is a resultant force. Taking moment at the C.G. of the rod, the forces will result in a net clockwise moment. 
21	A	The speed of magnet is lower at the beginning compared to the end, resulting in a higher magnitude and narrower time; and there is a reversal in the induced current.
22	D	Use left hand rule to check. The induced current will produce a force that is always opposing V. There is no current for option C.
23	C	Use right hand grip rule to check
24	A	mg = BIL (10/1000) x 9.81 = 0.4x 0.6 I I = 0.409, use left hand rule to produce an upward force. Current is from P to Q
25	C	The output voltage is 240/20 = 12 V, and output current is 12/5. Output power is 12x12/5, which is 0.95 of the input power. $\frac{12x12}{5}$ = 0.95x 240 I I = 0.126 A
26	A	$I_{rms} = \sqrt{\frac{2A^2}{4}} = \frac{A}{\sqrt{2}}$

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27	B	Using Einstein's Photoelectric Equation, $hf = \Phi + eV_s$ $3.5 \times 10^{-19} = \Phi + (1.6 \times 10^{-19})(0.25)$ $\Phi = 3.1 \times 10^{-19}$ J
28	C	Given that $E = \frac{1}{2} mv^2$, $mE = \frac{1}{2} m^2v^2$ $2mE = p^2$ $p = \sqrt{2mE}$ Using de Broglie's equation, $p = h / \lambda$ $\sqrt{2mE} = h / \lambda$ $\lambda = h / \sqrt{2mE}$ Therefore, given that h and m are constants, λ is proportional to $\frac{1}{\sqrt{E}}$
29	B	${}^{134+84}_{84}X \rightarrow {}^{132+82}_{82}Z + {}^{4}_{2}\alpha \rightarrow {}^{130+84}_{84}Y + 2\,{}^{0}_{-1}\beta$
30	C	Total rest masses of P and Q should be larger. Total momentum is constant. It is uncertain if BE per nucleon of X and Y are larger than P and Q.

End of solutions

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Solution for 2017 SAJC Prelim Paper 2

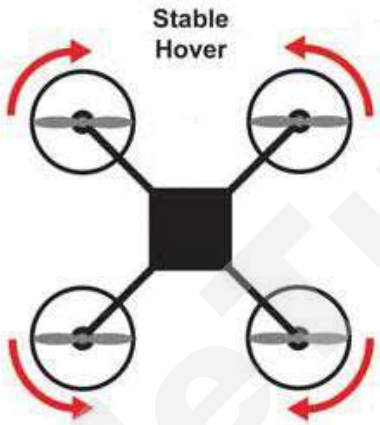
1 (a) **Torque of a couple:** The product of one of the forces of the couple and the perpendicular distance between the lines of action of the forces. [1]

A Couple is a pair of equal and opposite forces, whose lines of action do not coincide. (Hence it tends to produce rotation only) [1]

(b) Taking moment about the left string,
$T_R(2) = 1g(1) + 4.5g(1.5)$ [1]
$T_R = 38.0$ N [1]

$F_{net,y} = 0$
$T_L = (4.5+1)g - 38.0$
$T_L = 16.0$ N [1]

(c) (i)



[1]

(ii) The propellers produce a combined thrust / lift equal to the weight (of (0.330)(9.81) = 3.24 N)) [1]

(iii) Propellers 1 and 2 decrease speed equally (between 1 and 2) while propellers 3 and 4 increase speed equally (to tilt in order to have a component of force forward) [1]

After which, all four propellers should spin at the same speed that is faster than its original speed for hovering. [1]

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2 **(a)** The direction of the object changes continuously and hence there is a change in velocity of the object. [1]

Based on Newton's first law, this means that there must be a force acting on the object. [1]

Since the speed remains unchanged, this force cannot have a component tangential to the circle. This implies that the force is perpendicular to the velocity/displacement of object (so towards centre of circle). [1]

(b) For the block to just make it through the top of the loop, the weight is just providing for the centripetal force.

$mg = mv_{top}^2 / R$
$(0.50)(9.81) = (0.50)(v_{top}^2) / 1.5$
$v_{top} = 3.836 \text{ m s}^{-2}$ [1, also award if student leave as KE = 3.68 J]

By PCOE,

$KE_i + EPE_i + GPE_i$ – work done by friction = $KE_f + EPE_f + GPE_f$
$0 + ½ ke^2 + 0 – Fd = ½ mv_{top}^2 + 0 + mg(2R)$ [1]
$½ (78.4)(e^2) – (1.47)(2.5) = ½ (0.50)(3.836^2) + 0.50(9.81)(2 \times 1.5)$

Solving, e = 0.750 m [1]

(c) At the top of the motion, only weight provides for the centripetal force.

$mg = mr_1\omega^2$
$\omega = \text{sqrt}[(9.81) / 0.13] = 8.687 \text{ rad s}^{-1}$ [1]

Spring constant, $k = 5 / (0.148 – 0.13) = 278 \text{ N m}^{-1}$ [1]

(Since the mass is moving at constant angular velocity, at the bottom, ω is also 8.687 rad s^{-1}.)

Hence, at the bottom, tension – mg provides for centripetal force.

$T – mg = mr_2\omega^2$ (Note that $r_2 \neq r_1$)
$ke – mg = mr_2\omega^2$
$(277.8)(L – 0.13) – (5.0) = (5 / 9.81)(L)(8.687^2)$
[award 1 for substituting e = L – 0.13]

Solving, L = 0.172 = 17.2 cm [1]

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3 **(a)** k/m is a constant, therefore a is proportional to x [1]
'-' sign showed that a is opposite to x [1]

(b) $w^2 = k/m$
$(2\pi/T)^2 = k/m$ [1]
T = 1.57 s [1]

(max 1 mark for $T = \pi/2$)

(c) max KE = max EPE
$\frac{1}{2} mv^2 = \frac{1}{2} mw^2x_o^2$ [1]
$X_0 = 0.12$ m [1]

(d) Energy proportional to (amplitude)^2

$0.8 = \frac{x_0^2}{3^2}$ [1]
$X_o = 0.0268$ m [1]

(e) metal block experiences changing magnetic flux. Hence, by Faraday'EMF induced produces electric (eddy) current. [1]

Heat is generated in the metal block as a result of the flowing current. [1]

The energy of oscillation therefore decrease faster than without magnets.

OR

By Lenz's Law, there is an opposing magnetic force against the motion of oscillation. [1]

Work is done to overcome the opposing force, and hence the system decreases energy faster.

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4 **(a)** Electric field strength at a point is defined as the electric force per unit (positive) charge acting on a **small positive** test charge placed at that point. [1]

(b) **(i)** Like charges. There are equipotential lines that encompasses both charges.

[1]

Equal magnitude. The equipotential lines are symmetrical. [1]

(Award 1 mark for 2 out of 4 correct statements)

(ii) 90° [1]

No work is done when a (second) charge is moved along the same equipotential line since there is no change in potential. Hence, the direction of the electric force must be perpendicular to the displacement moved. [1]

(iii) Field lines drawn for like charges (repulsive) [1]

Field lines drawn should be roughly perpendicular to equipotential lines. [1]

(c) Potential at point M

= potential at point M due to q_1 + potential at point M due to q_2

$= (\frac{1}{4\pi\varepsilon_o})[\frac{35\times10^{-3}}{5} + \frac{-52\times10^{-3}}{4}]$

$= (8.99 \times 10^9)(-6 \times 10^{-3})$

$= -54.0 \times 10^6$ V [1]

Potential at point N

= potential at point M due to q_1 + potential at point M due to q_2

$= (\frac{1}{4\pi\varepsilon_o})[\frac{35\times10^{-3}}{4} + \frac{-52\times10^{-3}}{5}]$

$= (8.99 \times 10^9)(-1.65\times 10^{-3})$

$= -14.8 \times 10^6$ V [1]

Work Done to move the charge from point M to N

$= q\,\Delta V$

$= (4.5 \times 10^{-6})(-14.8 \times 10^6 + 54.0 \times 10^6)$

$= 176$ J

[1]

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5 **(a)** Induced e.m.f. is proportional (equal) to the rate of change of magnetic flux (linkage) [1]

(b) **(i)** Flux linkage = NBA
= 85 x (πx 10^{-3}x 2.8)x (π x (1.6 x 10^{-2})^2)
= 6.00 x 10^{-4} Wb [1]

(ii) Flux change = 2 x 6.00 x 10^{-4} [1]
Induced e.m.f. = 0.004 V [1]

(iii) 0 v for t = 0 to 0.3, t = 0.6 to 1.0 and t > 1.6 t [1]
0.004 V for t = 0.3 to 0.6 s [1]
- 0.002 V for t = 1.0 to 1.6 s [1]

(iv) rms of input = 2.55/$\sqrt{2}$ = 1.80 [1]

85 / 15 = V / 1.80
V = 10.2 V [1]

(v) flux leakage /incomplete flux linkage from primary coil to secondary coil [1]

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6 (a) (i) Ionisation energy = 10.4 eV = 1.66 x 10^{-18} J [1]

(ii) λ_3 is the longest wavelength emitted, corresponding to the lowest energy photon. [M1]

Therefore, transition is from E3 to E2, where the energy difference is the lowest. [A1]

(iii) When the current is passed through the gas, electron collides with the atom at ground state and pass energy equivalent to the difference of E_3 and ground state. [1]

The atom is excited up to a higher energy level at E3 (for about 10^{-8} seconds.) [1]

The atom will then de-excite to the lower energy state E2 by emitting a photon of energy with corresponding wavelength of λ_3. [1]

(b) (i) Stopping potential is the **minimum negative** potential required to stop the **fastest** electron from arriving at the collector plate. [1]

(ii) Number of photoelectrons emitted per second

$$= \frac{I}{q}$$

$$= \frac{0.34 \times 10^{-3}}{1.6 \times 10^{-19}}$$

= 2.125 x 10^{15} s^{-1} [1]

Number of incident photons per second

$$= \frac{P}{hf}$$

$$= \frac{P}{h\frac{c}{\lambda}}$$

$$= \frac{2.85 \times 10^{-3}}{(6.63 \times 10^{-34})(\frac{3.0 \times 10^{8}}{225 \times 10^{-9}})}$$

= 3.224 x 10^{15} s^{-1} [1]

Quantum yield

$$= \frac{2.125 \times 10^{15}}{3.224 \times 10^{15}}$$

= 0.659 [1]

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7 **(a)** As temperature increases, amplitude of the vibration of lattice ions become greater. M1
Thus drift velocity of electrons is lower. A1

(b) **(i)** series B1
(ii) parallel B1

(c) **(i)** The movement of the coolant is driven by heat loss from panel / cooling by convection current in the air / cooling without power input B1
(ii) Active cooling could fail / active cooling needs energy input, increasing costs or decreasing system output / difficult to eliminate passive cooling.B1

(d) Position panel so that there is an air gap around it
eg. mount panel a small distance above the roof / in open space / clear from obstructions / spaced out in a field. B1

(e) **(i)** V_R = 6.4 V, V = 7.6 V B1
(ii) At low voltages, there is little or no change to current with temperature. B1
At higher voltages, there is greater current at lower temperature. B1
(iii) best fit line drawn B1
(iv) μ = - gradient C1
μ = 0.12 V °C^{-1} (accept 0.11 V °C^{-1} to 0.13 V °C^{-1}) A1

When $T = T_R$, $V = V_R$ = 6.4 V
From graph, T_R = 25 °C (accept 24 °C to 26 °C) A1

(v) 7.6 = 0.12 (25 – T) + 6.4
T = 15 °C B1

(vi) rectangle drawn below line M1
correct area indicated (6.0V and 0.048 A) A1

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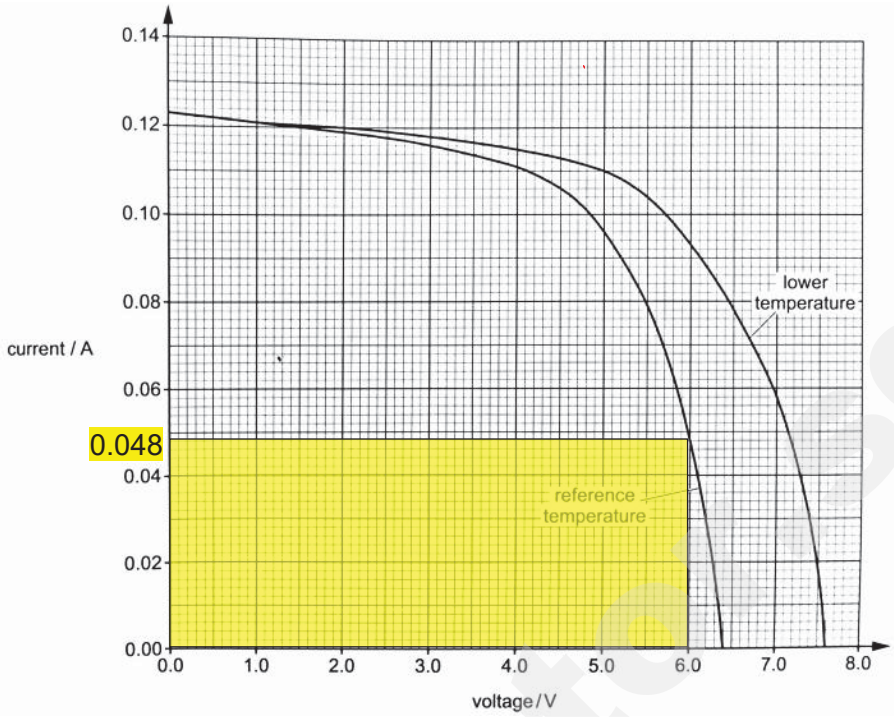

(vii) Use of area of rectangle or $P = IV$ C1
P = 0.5 W A1

(f) **(i)** Better chance of capturing photons OR photons of a greater range of frequencies (contained within sunlight) can be captured B1

(ii) Electrical output power increases as angle of incidence on panel decreases. B1

OR

The larger the angle between the PV panel and the incident sunlight, the larger the electrical power output. B1

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JC2 Preliminary Exam 2017 (H2 Physics)

Examiner's Report with answers for Paper 3

1 **(a)** $\Delta w = p\Delta V = 5.2 \times 10^5 \times (5 - 1.6) \times 10^{-4} = 176.8$ [1]

$\Delta U = 442 - 176.8 = 265$ J [1]

(b) No PE, decrease in U = decrease in KE. [1]
KE, (3/2 nRT), is proportional to T. So T decreases [1]

(c) $\Delta U = 313 - 265.2 = 47.8$
$\Delta W = (5 - 1.6) \times 10^{-4} \times (5.2 + 1) / 2 = 105.4$ J [1]

$\Delta Q = 47.8 - 105.4$
$\Delta Q = - 57.6$ J [1]

(d) $pV = nRT$
$5.2 \times 10^5 \times 1.6 \times 10^{-4} = n \times 8.31 \times (273.15 + 227)$ [1]

$n = 0.0200$
$N = 6.02 \times 10^{23}$ $n = 1.2 \times 10^{22}$ [1]

(e) $\frac{1}{2} \langle c^2 \rangle = \frac{3}{2} kT$
$\sqrt{\langle c^2 \rangle}$ proportional to $\sqrt{T}$ or $\sqrt{V}$ when P is constant [1]

$$\frac{\sqrt{\langle c^2 \rangle}}{350} = \sqrt{\frac{5}{1.6}}$$

$\sqrt{\langle c^2 \rangle} = 619$ m s^{-1} [1]

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2 **(a)** **(i)** Waves must have the same frequency or wavelength [1]
Waves must have the same amplitude [1]
Waves must be antiphase/180º or π radians apart [1]

(ii) Noise of engine is of one frequency/pitch while speech/music varies in pitch and/or frequency. [1]

(b) **Diffraction** refers to the **spreading** [bending] **of waves when they pass through an opening [gap]**, or round an obstacle into the "shadow" region. [1]

(c) $n_{max} \leq d/\lambda$ [1]

Since the diffraction grating produces up to only third order, $3 \leq d / \lambda < 4$

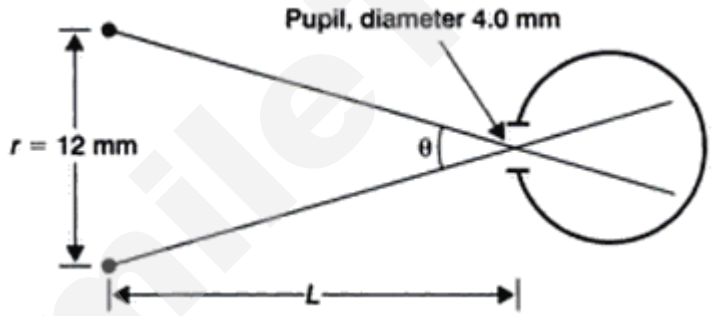
Thus, $3\lambda \leq d < 4\lambda$ [1]

(d) Slit width (gap between ribs) too wide compared to x-ray wavelengths, diffraction effects will not be pronounced enough. [1]

OR

Slit separation (thickness of ribs) too wide compared to x-ray wavelengths, all maxima will be deflected by negligible angle. [1]

(e)



The maximum value of L is found for the minimum value of θ, when the two sources separated by a distance of $r = 12 \times 10^{-3}$ m can just about be resolved.

$$\theta \approx \frac{\lambda}{d} = \frac{0.60 \times 10^{-6}}{4.0 \times 10^{-3}} = 0.15 \times 10^{-3} \text{ rad}$$ [1]

For small values of θ, then

$$L = \frac{r}{\theta} = \frac{12 \times 10^{-3}}{0.15 \times 10^{-3}} = 80 \text{ m}$$ [1]

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3 **(a)** **(i)** (V = 1.398 V, I = 0.31x10^{-3} A)
$R = V / I$ = **4.5 x 10^3 Ω** [2]

(ii) $R = \rho L/A$ [M1]
$\rightarrow \rho = RA/L$ = 4.5 x 10^3 x 0.800 x 0.210 / 0.900
= **840 Ω m** [A1, ECF]

(b) **(i)** 3 J of non-electrical energy is transformed into electrical energy for each coulomb of charge that passes through the battery. [1]

(ii) 2 J of electrical energy is transformed into non-electrical energy for each coulomb of charge that passes the resistor. [1]

(c) **(i)** emf = I (R_1 + R_2) = (200 x 10^{-6}) x(15 + 10) x 10^3 = **5.0 V** [1]

(ii) emf = I [R_v R_1/(R_v+ R_1) + R_2]

correct expression of R_{eq} for 15 kΩ // with voltmeter R_v [1]

5.0 V = (250 x 10^{-6}) [15 R_v /(R_v+ 15) + 10]x 10^3

Solving R_v = **30 kΩ** [2, ECF]

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4 **(a)** region of space where a moving charge/current carrying conductor experience a force [1]

(b) **(i)** out of the plane of the paper/page [1]

(ii) The force is perpendicular to the velocity [1]
No work done by the force, so KE does not increase [1]

(iii) Centripetal force provided by magnetic force
$Bqv = mv^2/r$ [1]

$d = 2r = 2mv/Bq$ [1]

(iv) $T = \frac{\pi d}{2v}$ [1]

$= \frac{\pi}{2v}(\frac{2mv}{Bq})$

$= \frac{\pi m}{Bq}$, independent of v [1]

(v) Helical path out of the page [1]

(vi) E-field lines pointing from right from left. [1]

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5 **(a)** **(i)** Smaller deviation (not zero deviation), acceptable path wrt position of N. [1]

(ii) The nucleus is small <u>in comparison</u> to the atom
OR
Atom is mostly empty space [1]

(iii) Deviation depends on charge of nucleus. [1]

Since nuclei of isotopes have same charge, there is no change in deviation.
(do not allow "isotopes have the same charge") [1]

(iv) β-particles have a range of energies **OR**
β-particles can be deviated by orbital electrons **OR**
β-particles have small masses [1]

(b) **(i)** 2 [1]

(ii) mass defect = 92(1.007u) + (235 - 92)(1.009u) – 235.123u = 1.808u [1]

binding energy = $1.808(1.66 \times 10^{-27})(3.00 \times 10^{8})^2 / (1.60 \times 10^{-19})$
= 1688 MeV [1]

binding energy per nucleon = 1688 / 235 = 7.18 MeV [1]

(iii) 8.09 MeV is the <u>average</u> energy required to completely separate each nucleon from molybdenum-95 nucleus. [1]

(iv) energy released = binding energy of products – binding energy of reactants + KE of reactants [1]
= 95(8.09) + 139(7.92) – 235(7.18) + 10.0
= 192 MeV [1]

(c) **(i)** $N = 1 \times 10^{-3} / (226 \times 1.66 \times 10^{-27}) = 2.666 \times 10^{21}$ [1]

$$A = \lambda N$$
$$= \frac{\ln 2}{t_{1/2}} N$$
$$= \frac{\ln 2}{1600 \times 365 \times 24 \times 60 \times 60}(2.666 \times 10^{21})$$
$= 3.7 \times 10^{10}$ Bq [1]

(ii) The parent nuclei that decay to form radium-226 have long half-life. [1]

(d) **(i)** fraction of the total no. of undecayed nuclei which will decay per unit time
OR
the probability of a nucleus decaying per unit time. [1]

(ii) $C = C_0 e^{-\lambda t}$
$228 = 538\ e^{-\lambda(8.0)}$ [1]
$\lambda = 0.107\ h^{-1}$

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$t_{1/2}$ = ln2 / 0.107 = 6.5 h [1]

(iii) random nature of decay
background radiation
daughter product is radioactive
(any 2 sensible suggestions, [1] each)

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Section B

6 (a) (i) $s_y = u_y t + ½ a t^2$

$0 = 800 \sin 50° (t) + ½ (-9.81) (t^2)$ [1]

$t = 125$ s [1]

$s_x = u_x t = 800 \cos 50° (125) = 64.2$ km [1. ecf]

(ii) Angle = 40° [1]

(iii) Time of flight is shorter. [1]

(b) (i) To find the distance travelled while accelerating to max speed,

$v^2 = u^2 + 2as$

$(60000 / 3600)^2 = 0 + 2(1)(s)$

$s = 138.89$ [1]

To find time required to reach maximum speed,

$s = ut_1 + ½ at_1^2$

$138.89 = 0 + ½ (1)(t_1)^2$

$t_1 = 16.67$ s [1]

To find the time taken to travel remaining distance at top speed,

$s = ut_2$

$3000 – 138.89 = (60000 / 3600)(t_2)$

$t_2 = 171.67$ s [1]

Minimum time required = $t_1 + t_2 = 171.67 + 16.67 = 188.3$ s [1, ecf]

Alternatively,

To find time required to reach maximum speed,

$v = u + at_1$

$60000 / 3600 = 0 + (1)(t_1)$

$t_1 = 16.67$ s [1]

To find the distance travelled while accelerating to max speed,

$s = ut + ½ at2$

$= 0 + ½ (1)(16.67)2$

$= 138.89$ m [1]

To find the time taken to travel remaining distance at top speed,

$s = ut_2$

$3000 – 138.89 = (60000 / 3600)(t_2)$

$t_2 = 171.67$ s [1]

Minimum time required = $t_1 + t_2 = 171.67 + 16.67 = 188.3$ s [1, ecf]

(ii) time required = 188.3 – 125 = 63.3 s [1, ecf]

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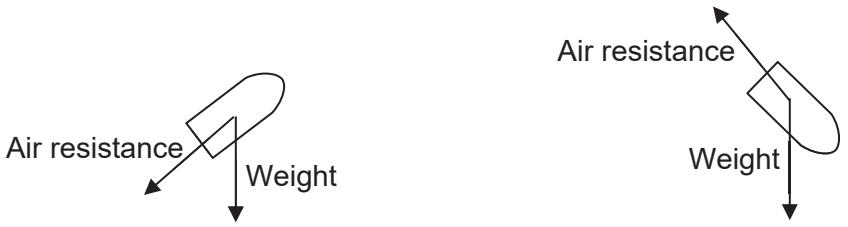
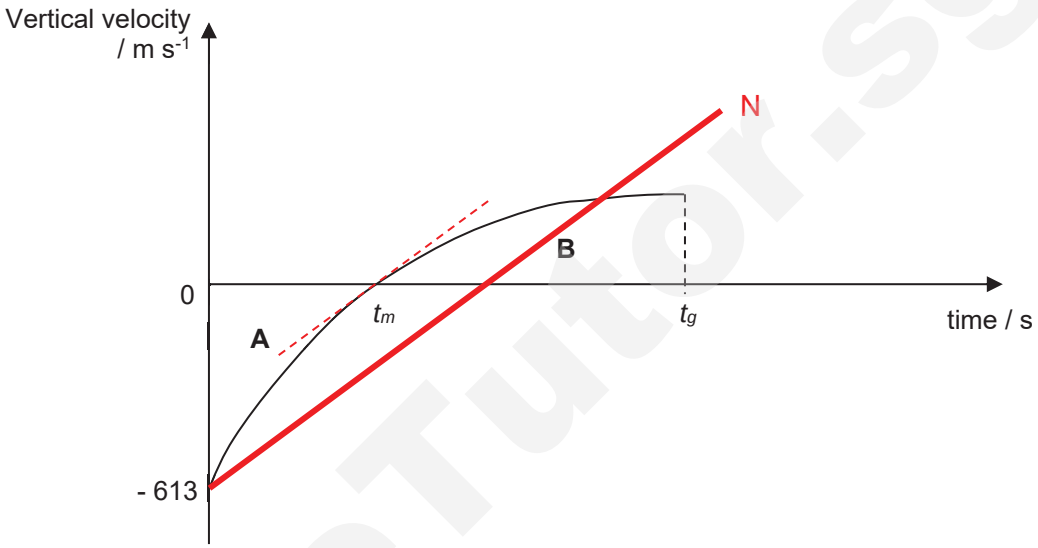
(c) (i)



(Minus 1 mark for each missing vector or label.) [2]

(ii)



Correct shape and sign [1]
Larger initial velocity (lower final velocity) [1]
Approximately equal area before and after reach max height (A = B) [1]
(Not a marking pt, but good to know $t_m < t_g - t_m$)

(iii) Upward sloping straight line [1, ECF for sign]
Gradient of line N to be parallel to tangent at t_m for (ii) [1]

(iv) The net accelerating force (*W – air resistance*) (or net acceleration) when the projectile is moving downwards is always smaller than the retarding force (*W + air resistance*) (or deceleration) when it is moving upwards. [1]

Since the distance travelled upwards is the same as the distance travelled downwards, time taken for it to travel to the maximum height will be shorter than the time taken for the projectile to return to the ground. [1]

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(d) (i) It cannot be applied as there is an external force acting on the system. [1]

The ground exerts an normal contact force on the gun / Weight is acting on the projectile etc [1]

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7 **(a)** **(i)** rate of change of angular displacement with respect to time. [1]

(ii) One radian is defined as the angular displacement of an object in circular motion where the ratio of the arc length *s*, and the radius *r*, is equal to 1. [1]

(b) **(i)** velocity in m s^{-1} = 68 x $(\frac{1000}{3600})$ = 18.89 m s^{-1} [1]

Resultant force = centripetal force = $\frac{mv^2}{r}$

$= \frac{(900)(18.89)^2}{19.0}$ [1]

= 16900 N [1]

(ii) Sideway (or lateral) friction between (tyre and road). [1]

(iii) For the F1 car to maneuver at a higher speed, a larger centripetal force is required. [1]

This can be provided by the horizontal component of the normal reaction force that the road acts on the race car. [1]

(c) Properties:

- Orbits west to east over equator
- Maintains a fixed position relative to Earth's rotation
- Period is 24 hrs (1 day) or same as Earth's rotation

Advantages :

- Offers uninterrupted communication between transmitter and receiver
- Allow the satellite to monitor the same area at all time
- Satellite dish need not be steerable

(d) **(i)** $F = \frac{GMm}{r^2} = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(2.5 \times 10^{3})}{(1.6 \times 10^{7})^2}$ [1]

= 3910 N [1]

(ii) $v_{orbit} = -\frac{GM}{r} = -\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{1.6 \times 10^{7}}$

= - 25 MJ kg^{-1} [1]

Increase in potential = - 25 – (- 63) = 38 x 10^6 J kg^{-1} [1]

Increase in potential energy = $m\Delta V$ = $(2.5 \times 10^3)(38 \times 10^6)$

= 9.5×10^{10} J [1]

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(e) $\omega = \frac{2\pi}{T} = \frac{2\pi}{7.15 \times 24 \times 3600} = 1.02 \times 10^{-5}$ rad s^{-1} [1]

Centripetal acceleration of Jupiter, $g = \omega^2 r = (1.02 \times 10^{-5})^2(1.07 \times 10^9)$
$= 0.111$ m s^{-2} [1]

Since $g = \frac{GM}{r^2}$, $M = \frac{gr^2}{G} = \frac{(0.111)(1.07 \times 10^9)^2}{6.67 \times 10^{-11}}$ [1]
$= 1.91 \times 10^{27}$ kg [1]

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Apparatus List for Q1

1. Two springs
2. Two stands, bosses and clamps
3. Hacksaw blade
4. Two corks, with slits to grip to grip the hacksaw blade in retort clamps
5. Five 100 g slotted masses loaded onto a 100 g mass hanger
6. Small ring (eg keyring)
7. 30 cm rule with a millimetre scale
8. Protractor

The hacksaw blade, springs, ring and masses should be assembled as shown in Fig. 4.2

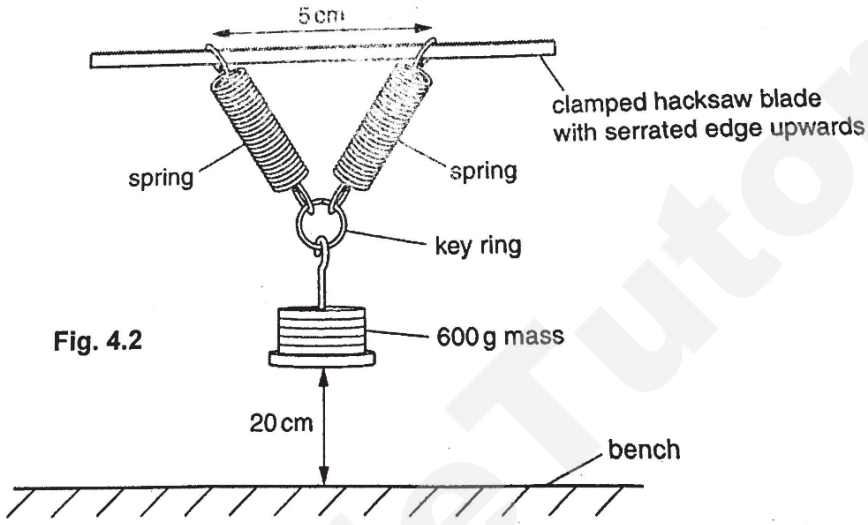

Fig. 4.2

Apparatus List for Q2

1. A ball of modelling clay (of mass 50 g)
2. A flat metal/wooden board
3. Vernier caliper
4. A stopwatch
5. Retort stand, clamp and boss-head
6. Rubber band
7. Nail
8. Sellotape & scissors

Apparatus List for Q3

1. 1.5 V dry cell with holder
2. A digital ammeter set to the 200 μA (dc) range
3. Six connecting leads
4. A 0 – 3 V dc analogue voltmeter
5. Two resistors one labelled 'R_1' and the other labelled 'R_2'.
   Each of the resistors is securely placed in a component holder.

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Markscheme for Prelim Physics Practical: Q1

(a) [1]

- Repeated readings of L_0 & average recorded to **nearest 0.001 m** (ie 0.1 cm)
- Acceptable **range:** 2.0 – 2.4 cm

(c) Successful collection of **5 or more sets** of raw data (ie of θ & L) where **$30^0 < \theta < 80^0$** without assistance **[2]**

{1 mark for 4 sets, zero mark for 3 or less sets.
Deduct up to 2 marks if student requires assistance}.

Range of Data/Independent Variable: **Range of $\theta \geq 35^0$** [1]

Column Heading & Tabulation [1]

- Each column heading must contain a **quantity and a unit**:
  $\theta/^0$, L/m , $\frac{1}{\cos(\frac{\theta}{2}/^\circ)}$
- No split tables, ie readings of $\frac{1}{\cos(\theta/2)}$ tabulated with θ & L.

Raw Data (ie of θ & L): Precision of Recording [1]

- All values of θ **to nearest degree** &
- All values of L **to nearest 0.001 m {ie 0.1 cm}**

Calculated Quantities: Precision & Consistency [1]

All values of $\frac{1}{\cos(\theta/2)}$ **consistently** recorded to same number of **s.f.** as θ or, consistently 1 more sf.

Calculated Quantities: Accuracy of Calculation [1]

All values of $\frac{1}{\cos(\theta/2)}$ correctly calculated.

(d) Why minimum value of θ was restricted to 30^0: [1]

For $\theta < 30^0$, the lower ends of springs may come into **contact** with each other (which will introduce an error to the value of θ.)

(e) (i) Graph: Scale, Size & Axes [1]

- Sensible scales, no awkward scales (eg 3 units into 10 small squares)
- Plotted pts occupy at least ½ **the graph grid in both x & y directions**

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- Axes labelled with the quantity & unit {ECF for wrong units in (c)}
- Successive scale markings: no more than 20 small squares apart.

Plotting of Points [1]

- ALL observations in table must be plotted
- accurate to within half a small square.
- **Thickness of plots** (ie the crosses, 'x') ≤ half a small square

Best fit line & Anomaly [1]

- **Minimum number of 4** non-anomalous pts.
- Line drawn with **approx. equal number** of points on either side of line (anomalous pts not considered).
- Line not be kinked/disjointed or thicker than half a small square
- Anomalous plot **clearly indicated** (eg by a circle or labelled.)
  Allow 1 anomalous plot only.

(e) (ii) Determination of Gradient [1]

- Recording of the **4 coordinates** accurate to **half a small square**
- Hypotenuse of triangle **> half length** of line drawn
- **No obscurity** of the 2 pts used for gradient calculation
- Gradient calculated correctly & number of sf follows the lowest no. of s.f. among the 4 coordinates {or one more}.
- Unit for gradient: $\mathbf{m^{-1}}$

(e) (iii) Determination of y-intercept [1]

- Vertical intercept calculated using a point on the line {not from the table} & value of gradient.
  {Allow reading off the y- intercept (to the correct number of decimal places which is determined by ½ small sq for y-axis}) if x-axis starts from zero & there is no 'bunching of plots' }
- Unit for y-intercept: **no unit**

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(f) Linearisation of Eqn $\frac{1}{\cos(\theta/2)}$ = P L – Q { unnecessary for this question}

- Stated **explicitly**: *P* = gradient of graph [1]
- Stated explicitly:*Q* = y-intercept {Accept answer which omits this statement}

Q/P calculated correctly, recorded to **correct sf & unit** { metre }: [1]

(g) 2 Significant Sources of Error **[2]**

- **In the measurement of θ,** error arises as the **axes of the springs that define θ are imaginary**/not well-defined, (as well as parallax error), or

- **In the measurement of *L***, error arises due to the **unsteadiness of the hands** in holding the rule.

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Markscheme for Prelim Physics Practical: Q2

(a) (ii) Repeated readings of *d* & average recorded to **precision denoted by *Δd* in (iii)** [1]

- Within specified range**:** 4 - 5 cm

(iii) Percentage uncertainty in *d* correctly calculated with **2 mm ≤ Δd < 8 mm** [1]

& recorded to **1 or 2 sf** (not 3 sf).

(c) (ii) Determination of *T* [1]

- **Repeated timings** to **nearest 0.1 s**
- Timings for oscillations must be such that ***nT*** **≥10** s, where ***n*****, no. of oscillations is recorded**.
- Appropriate number of **sf** for *T*

(d) (iii) **Repeated readings** of *d* & **average** recorded to **nearest 1 mm** [1,ecf]

- Acceptable value**:** {must be > 6 cm as specified}

Determination of *T* [1,ecf]

- **Repeated timings** to **nearest 0.1 s**
- Timings for oscillations must be such that ***nT*** **≥ 10** s, where ***n***, **no. of oscillations** is recorded.
- Value of T > value in (c) (ii)
- Appropriate number of **sf** for *T*.

(e) (i) Calculation of 2 values of *k* [1]

- 2 values of *k* **calculated correctly** & recorded to **appropriate number of sf** [which is to the same no of sf as T or d {whichever is the smaller} , or 1 more]
- Unit of k : $\mathbf{s^2\ m^{-3}}$

(ii) Justification of Conclusion: [1]

The criterion here is, whether or not,

$$\frac{\Delta k}{k_{ave}} \textbf{ x 100\% > a stated reasonable Percentage Error}$$

If yes, ⇒ results do not support suggested relationship.

(f) (i) Any 2 significant sources of error: **[2]**

- Uncertainty in measuring *d* due to the variation in diameter of the **irregularly-shaped** piece of clay, or,
  due to the very soft clay, it is easily compressed when touched.

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- Difficult to ensure that timing is stopped at the right instant ie when cylinder is at the same position as when timing began.
- Any other reasonable answer

(ii) Improvements: **[2]**

- Use a less malleable clay (ie less compressible clay), or ,
  use a circular mould
  Use a fiducial marker (ie a point of reference) placed at the centre of oscillation,
  or, use video camera with timer/frame by frame playback.
- Any other reasonable answer,

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Markscheme for Prelim Physics Practical: Q3

(b) Recording of V_0 & I_0 [1]

- V_0 to the nearest 0.05 V
- I_0 to the nearest 0.1 μA
- Accurate values obtained: $V_0 \approx 1.50 \pm 0.20$ V, $I_0 \approx \{120.0 - 140.0\} \times 10^{-6}$ A

(c)(ii) Recording of V_2 & I_2 [1]

- V_2 to the nearest 0.05 V {ecf}
- I_2 to the nearest 0.1 μA {ecf}
- *Values of V_2 & I_2 *are very close to* V_1 & I_1 respectively *{since* $R_1 = R_2$*}*
- Accurate values obtained: $V_2 \approx$ 0.30 - 0.40 V, $I_2 \approx 178.2$ μA

(d) **[2]**

- Resistance of voltmeter is not >> R_1 (or R_2)/Voltmeter resistance is not infinite
- Explained consequence of point above { eg, "When voltmeter is connected across R_1, effective resistance across resistor R_1 becomes less than value of R_1" .}

(e) (ii) V_3 = 0.30 V, $I_3 = 100.4 \times 10^{-6}$ *A* [0]

(e) (iii) (Assume internal resistances of cell & of ammeter are negligible, & since $R_1 \approx R_2$)
Thus emf = V_0 in Fig. 3.1)

- In Fig 3.2: $V_0 = V_3 + I_3 [R_1 + R_2]$
  ie $1.50 = 0.30 + 100.4 \times 10^{-6} [2R_1]$ (eqn A)

  → **$R_1 = 6.00 \times 10^3\ \Omega$** [1]

- Since $V_3 = I_3 R_v$, R_v = *voltmeter resistance,* from Fig. 3.2*:*

  → Voltmeter resistance $R_v = (0.30\text{ V}) \div (100.4 \times 10^{-6}\text{ A}) =$ **$3.00 \times 10^3\ \Omega$** [1]

(e) (iv) From eqn (A), R_1 should have the same number of sf as V_3 (the quant with least no. of sf) or one more. Since V_3 has 2 sf, R_1 can have {2 or 3} sf. [1]

(e) (v) One Change to apparatus (in Fig. 3.1) to obtain more accurate value for R_1: [1]
Replace the analogue voltmeter with a voltmeter with a higher resistance, or a digital voltmeter or, a potentiometer.

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Markscheme for Prelim Physics Practical: Q4 (Planning)

Written Account	Marks
A Clear Labelled Diagram of Layout of Essential Apparatus • Parallel connection of voltmeter/CRO across 2 electrodes {or the high voltage supply} connected to high voltage supply • Apparatus above placed within transparent thermally-insulated chamber. (Each electrode is held by retort stand & clamp arrangement.) {Power supply may be outside of chamber} {*Alternatively, these 2 marks may be credited at the written account*.}	1 1
B Identified Independent & Dependent Variables • Independent Variable: temperature of air in chamber • Dependent Variable: minimum pd across electrodes when spark is generated	1 (both correct, '**minimum'** is essential)
C Control of Variables (ie stated how other variables that affect V_{min} are kept const): • Distance between the electrodes is kept constant (by monitoring with vernier caliper), or, • Pressure within chamber using vacuum pump & pressure gauge	1(for either)
D How Variables are Measured/Varied: • Voltage across electrodes: voltmeter or (calibrated) CRO • Temperature of air in chamber: measured by a **thermocouple**/ temperature sensor attached to data logger • Temperature is varied by the use of an electrical **heater**/heating element with a thermostat {Unacceptable: Bunsen burner, thermostat on its own}	1 1 1
E Basic Procedure 1. Set up the apparatus as shown in the diagram 2. Measure the temperature of the air in the chamber using a thermocouple (placed near the electrodes). 3. Use the high voltage power supply to **slowly increase** the voltage across the electrodes **from a low value** until a spark is generated. Measure this voltage (V_{min}). 4. Repeat steps 2 & 3 to get several sets of readings of T & V_{min}.	1 for stating both: • at a given T, V is measured & • several sets of these readings are obtained at different T

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F Analysis • Assume the relationship is $V_{min} = k\ T^n$, where k & n are constants. • Plot a graph of lg V_{min} against lg T. • If a linear graph is obtained, my assumed relationship is valid, where n is the gradient and $k = 10^{y\text{-intercept}}$.	(1 for all 3 pts correct)
G Safety Precaution (Any 1) • Keep hands dry and wear gloves (to minimise risk of electrocution when handling high voltage supply.) • Monitor the pressure constantly to minimise risk of explosion/implosion • Use goggles to view spark {possible danger of uv radiation} • Any other reasonable safety precaution (eg 'don't touch plates')	Max of 1
H Good Experimental Features/ Details • Stated how the **minimum** voltage for sparking to occur was determined (by a '**slow increase** of the voltage **from a low value**") • Any 2 from: ✓ thermocouple is calibrated {ie thermocouple emf is first calibrated to temperature} ✓ sufficient time allowed for air in chamber to reach equilibrium before recording T ✓ lighting condition is low so that spark can be seen easily ✓ chamber must be properly sealed to ensure reliable pressure readings <u>Less significant ones</u>: ✓ repeat measurement of voltage and taking the average ✓ switch off circuit when not taking readings to prevent overheating of apparatus	Max of 3 1 2

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TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

PHYSICS

9749/01

Paper 1 Multiple Choice

18 September 2017
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and Civics group on the Answer Sheet in the spaces provided.

There are **thirty** questions in this paper. Answer **all** questions. For each question there are four possible answers, **A**, **B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1} $(1 / (36\pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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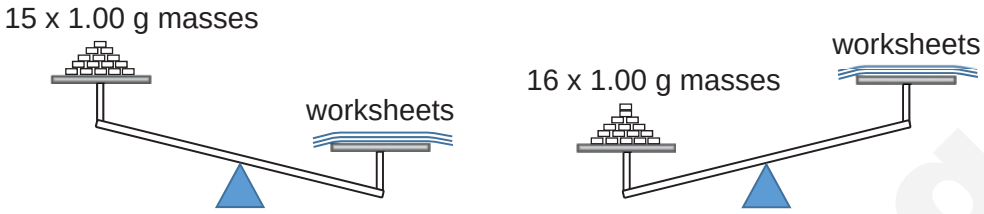
1 A Physics student measures the mass of his Measurement tutorial worksheets using a simple balance and some standard masses, each of 1.00 ± 0.02 g. He finds that 15 masses are not quite enough for balance but 16 masses are just too much.



What is an appropriate value, with its associated uncertainty, for the mass of the worksheets?

A 15.50 ± 0.02 g **B** 15.5 ± 0.3 g **C** 15.5 ± 0.5 g **D** 15.5 ± 0.8 g

2 A man is running on a horizontal road towards the north at 8 km h^{-1} in the rain. He sees the rain drops falling vertically as he runs. He increases his speed to 16 km h^{-1} and finds that the rain drops now make an angle of 30° with the vertical.

What is the velocity of the rain drops?

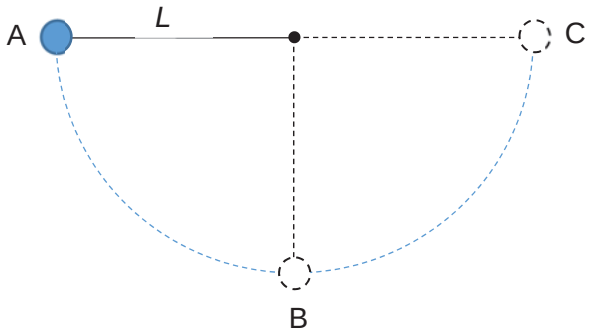
A 16 km h^{-1}, 30° with the vertical, downwards and northwards

B 16 km h^{-1}, 30° with the vertical, downwards and southwards

C 32 km h^{-1}, 30° with the vertical, downwards and northwards

D 32 km h^{-1}, 30° with the vertical, downwards and southwards

3 A pendulum of length L is released from A and swings to C where it comes to rest momentarily as shown. It follows a circular path and has maximum velocity at B.



What is the average velocity of the pendulum bob as it moves from A to C, if the time taken is T?

A 0 **B** $\frac{\sqrt{2gL}}{2}$ **C** $\frac{2L}{T}$ **D** $\frac{\pi L}{T}$

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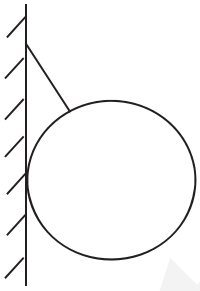
4 Water drops fall from rest at regular intervals from a tap which is 5.00 m above the ground. The third drop is leaving the tap at the instant the first drop reaches the ground.

How far above the ground is the second drop at that instant?

A 1.25 m **B** 2.50 m **C** 2.78 m **D** 3.75 m

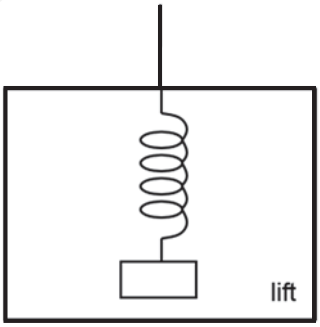
5 The diagram shows a uniform sphere of weight W attached to a smooth wall by a string of length equal to its radius.



What is the tension in the string?

A $2\,W$ **B** $2\sqrt{3}\,W$ **C** $\frac{2W}{\sqrt{3}}$ **D** $\frac{W}{2}$

6 A light spring of natural length 25.0 cm is suspended from the ceiling of a lift. A mass is hung from the end of the spring, as shown in the figure below.



When the lift is moving downwards at a constant speed, the length of the spring is 50.0 cm. The lift then slows down with a constant acceleration of 2.0 m s^{-2}.

Which of the following is correct? (Take g = 10.0 m s^{-2}.)

A The spring shortens by a length of 5.0 cm.

B The spring lengthens by a length of 5.0 cm.

C The spring shortens by a length of 10.0 cm.

D The spring lengthens by a length of 10.0 cm.

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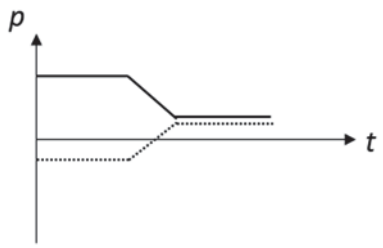
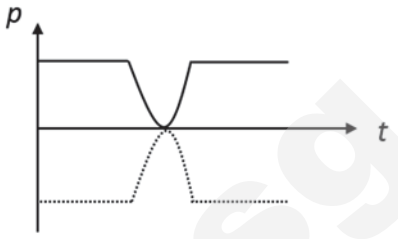
7 Two vehicles, not necessarily of the same mass or momentum, approach one another with constant velocities along a linear air track and make a head-on collision. The graphs below show the momentum of each vehicle against time for the period just before the collision until just after it. Which of the following graphs is **not** possible?

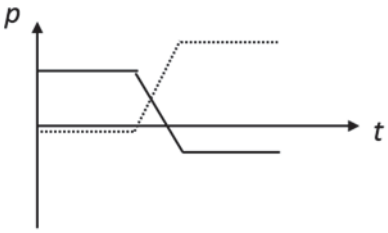
A



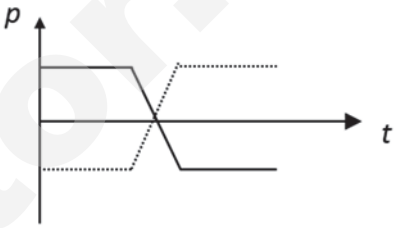
B



C



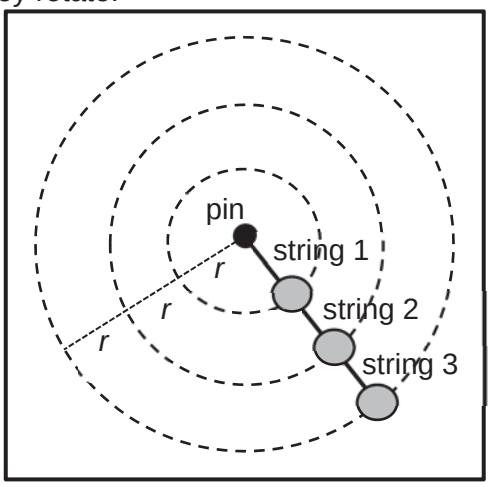
D



8 A crane lifting a container out of the hold of a ship is working at a rate of 670 kW. The container has a mass of 40 tonnes and is rising with a constant speed of 1.3 m s^{-1}.
(1 tonne = 1000 kg)
What is the efficiency of the arrangement?

A 0.078% **B** 7.8% **C** 59% **D** 76%

9 Three identical masses are tied together using strings and made to rotate around a pin on a smooth horizontal table as shown in the figure. The three masses remain in a straight line as they rotate.



plan view of setup

Which of the following gives the ratio of the tensions in string 1, string 2 and string 3?

A 1 : 2 : 3 **B** 3 : 2 : 1 **C** 3 : 5 : 6 **D** 6 : 5 : 3

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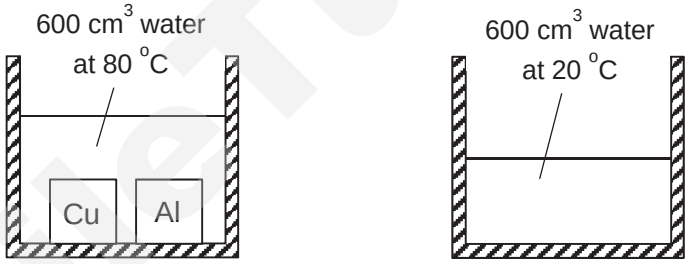
10 Four planets A, B, C and D have masses and radii as listed in terms of M and R where M and R are the mass and radius of the Earth respectively.

Which planet would have a surface escape velocity which is the same as that of the Earth?

	mass of planet	radius of planet
A	$\frac{1}{2}M$	$\frac{1}{\sqrt{2}}R$
B	$\frac{1}{2}M$	R
C	M	$\frac{1}{2}R$
D	$2M$	$2R$

11 Cup 1 contains 600 cm^3 of water, a copper (Cu) block, and an aluminium (Al) block. The copper block has a heat capacity that is larger than the heat capacity of the aluminium block.



cup 1 cup 2

Initially, the water in cup 1 is at 80 °C and in thermal equilibrium with both blocks. Both the blocks are then moved to cup 2, which is filled with 600 cm^3 of water initially at 20 °C. The water and the blocks are allowed to reach thermal equilibrium. Assume that negligible heat is lost to the air and cups.

Which of the following options correctly describes the ratio

$$\frac{(\text{Heat transferred from Cu block to water in cup 2})}{(\text{Heat transferred from Al block to water in cup 2})}?$$

A < 1

B = 1

C > 1

D Cannot be determined as the masses of the blocks are unknown.

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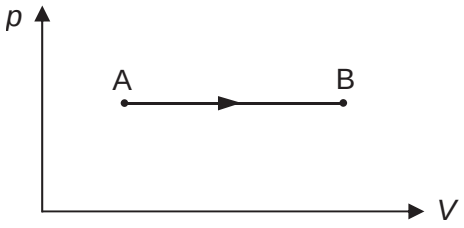
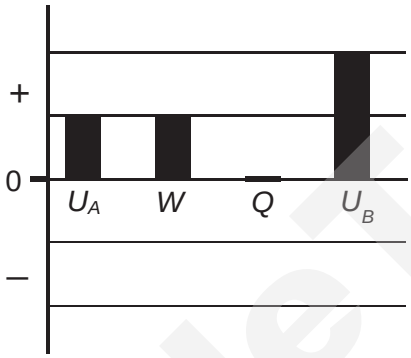
12 An ideal gas undergoes an isobaric process from state A to state B as shown in the *p*-*V* graph.



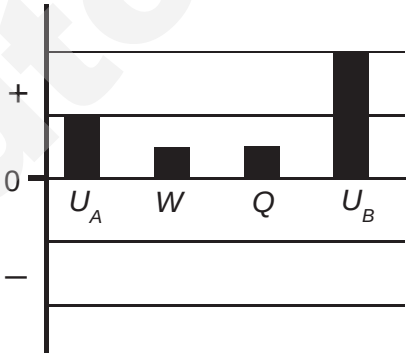
U_A and U_B are the internal energies of the gas in state A and state B respectively. W is the work done on the gas and Q is the heat input to the gas.

Which of the following bar-charts correctly represents the quantities U_A, U_B, W and Q?

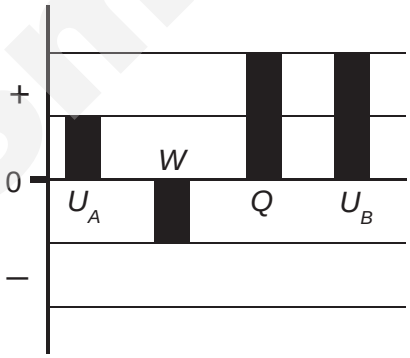
A



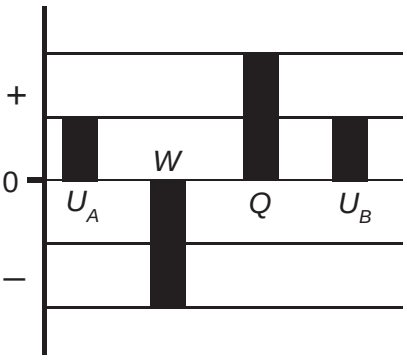
B



C



D



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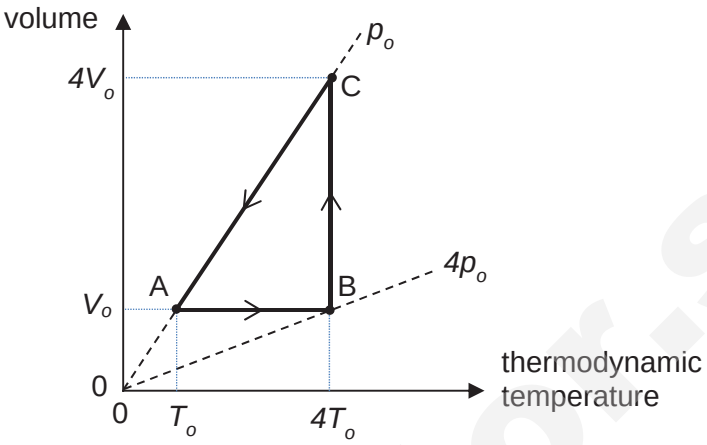
13 A fixed mass of ideal gas undergoes a cyclic process ABCA as shown. At state A, the gas has temperature T_o and volume V_o. The dashed lines are two isobars along which the pressure of the gas is constant. The values of the pressures for the isobars are p_o and $4p_o$.



Which of the following statements is **false**?

A For process AB, heat input is positive.

B For process BC, heat input is zero.

C For process CA, heat input is negative.

D For process ABCA, net heat input is positive.

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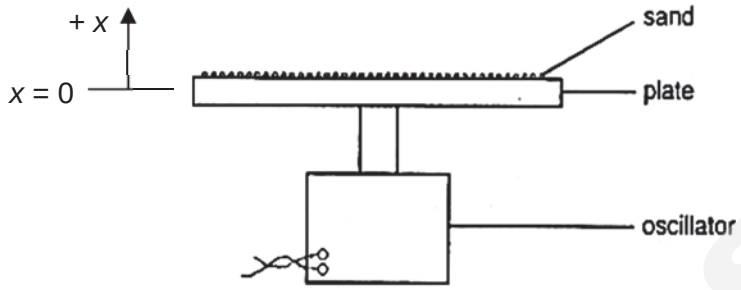
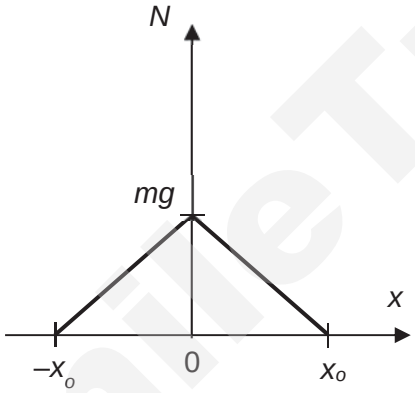
14 Some sand is placed on a flat horizontal plate and the plate is made to oscillate with simple harmonic motion in a vertical x-direction, as shown. The amplitude of oscillation x_o of the plate is such that the maximum acceleration is equal to the acceleration of free fall.

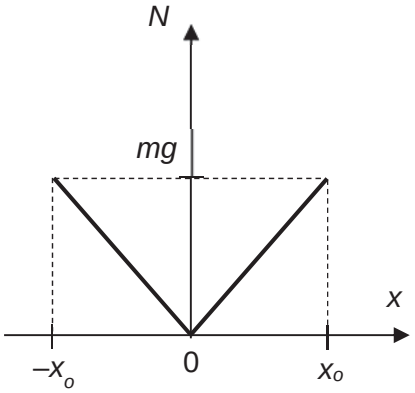


Which of the following graphs correctly describes the variation of the normal contact force N that the plate exerts on a grain of sand of mass m, with respect to the vertical displacement x of the plate?

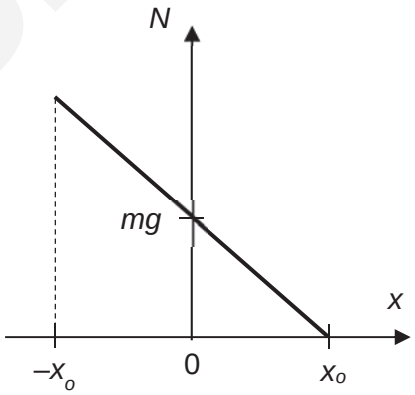
A



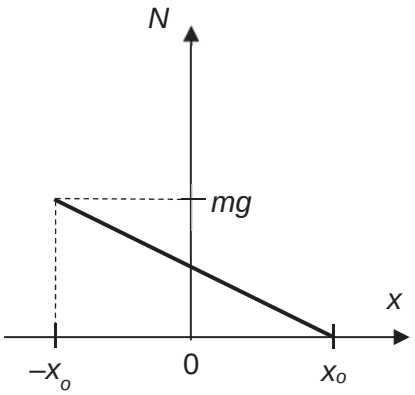
B



C



D



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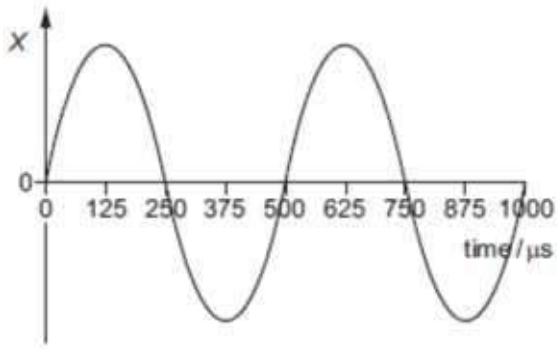
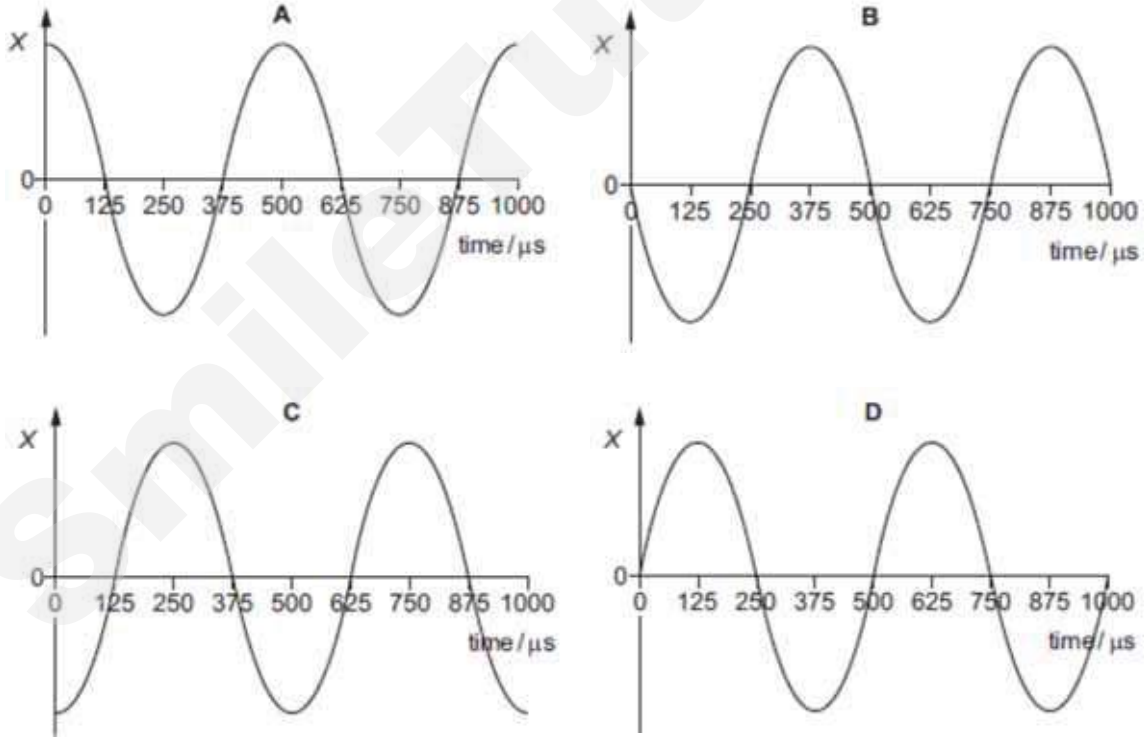
15 The graph shows the variation with time of the displacement X of a gas molecule as a continuous sound wave passes through a gas.



The velocity of sound in the gas is 330 m s^{-1}. All the graphs below have the same zero time as the graph above.

What is the displacement-time graph for a molecule that is a distance of 0.289 m further away from the source of the sound?



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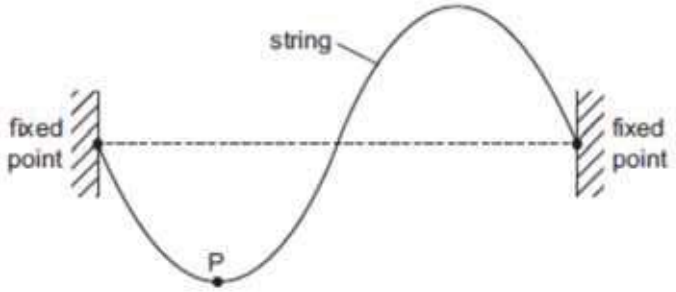
16 A stationary wave is formed on a stretched string. The diagram illustrates the string at an instant of time when the displacement of the string is at its maximum.



The frequency of the wave is 250 Hz. Point P on the string has a vertical displacement of –1.0 mm. What will be the vertical displacement of the point P after a time of 5 ms?

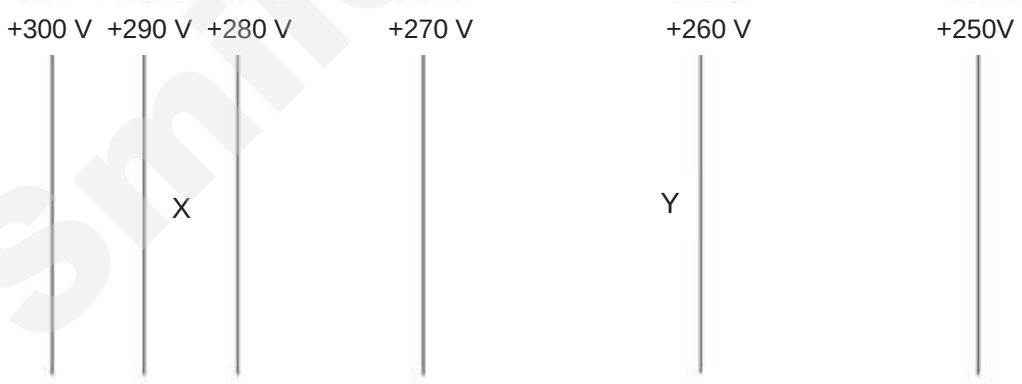
A –0.5 mm **B** zero **C** + 0.5 mm **D** + 1.0 mm

17 Two sources of radio waves are at a distance of 1.0×10^{15} m from Earth. The sources are separated by 1.0×10^{12} m and emit radio waves of wavelength 0.030 m.

What is the estimate for the diameter of a dish of a radio telescope on Earth that will just resolve the two sources?

A 0.30 m **B** 3.0 m **C** 30 m **D** 300 m

18 The figure shows some equipotential lines in an electric field.



The magnitude of the electric field strength at X is E_X and at Y is E_Y.

Which one of the following correctly compares E_X and E_Y and gives the correct directions of the electric field?

	Magnitude of electric field strength	Direction of electric field
A	$E_X > E_Y$	X → Y
B	$E_X > E_Y$	Y → X
C	$E_X < E_Y$	X → Y
D	$E_X < E_Y$	Y → X

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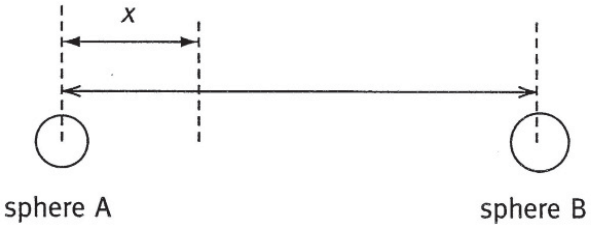
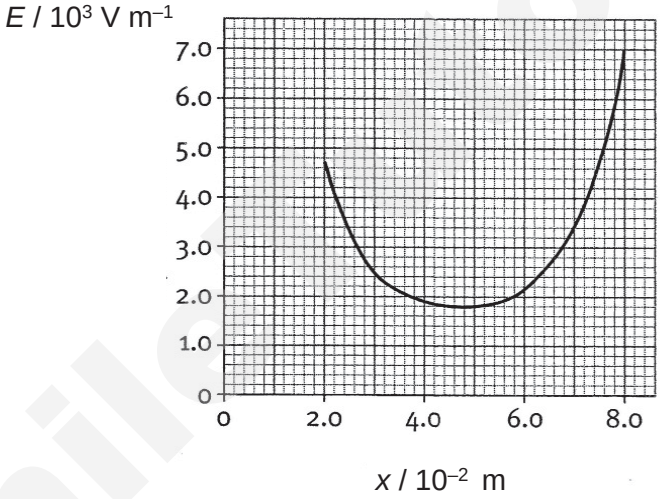
19 Two charged conducting spheres, each of radius 1.0 cm, are placed with their centres 10.0 cm apart as shown below.



Sphere A carries a charge of + 2.0 x 10^{-10} C.

The graph below shows how the resultant electric field strength *E*, between the two spheres, varies with distance *x*.



Which of the following correctly gives the magnitude of the electric field strength E_B due to the charge on sphere B at the 5.0 cm mark, and the sign of the charge on sphere B?

	magnitude of E_B / V m^{-1}	charge on sphere B
A	1.08 x 10^3	positive
B	1.08 x 10^3	negative
C	1.76 x 10^3	positive
D	1.76 x 10^3	negative

20 What is the **definition** of resistance?

A It is the ratio of the voltage to the current.
B It is the gradient of the graph of potential difference against current.
C It is the voltage required for a current of one ampere.
D It is the product of the resistivity of the material and the length of the wire divided by its area of cross-section.

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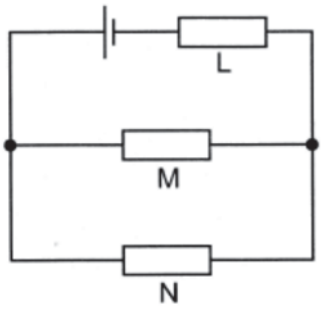
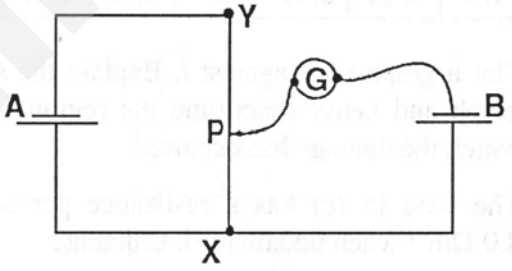
21 In the circuit shown, a battery supplies a current of 0.025 A for 80 s. During this time it produces 18 J of electrical energy while resistor M receives 11 J and resistor N receives 4.0 J.



What is the e.m.f. of the battery and its internal resistance L?

	e.m.f. of battery / V	internal resistance L of battery / Ω
A	1.5	60
B	9.0	60
C	9.0	360
D	16.5	360

22 In the circuit shown below, cell A has a constant e.m.f. and negligible internal resistance. Wire XY is 100 cm long with a resistance of 5.0 Ω. Cell B has an e.m.f. of 1.5 V and an internal resistance of 0.80 Ω. The length XP required to produce zero current in the galvanometer is 75 cm.



In which of the following arrangements would the length XP, required to produce zero current in the galvanometer, be 90 cm?

A When a 1.0 Ω resistor is connected in parallel with cell A

B When a 1.0 Ω resistor is connected in parallel with cell B

C When a 1.0 Ω resistor is connected in series with cell A

D When a 1.0 Ω resistor is connected in series with cell B

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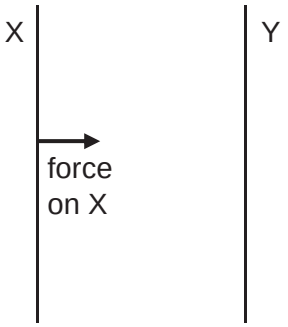
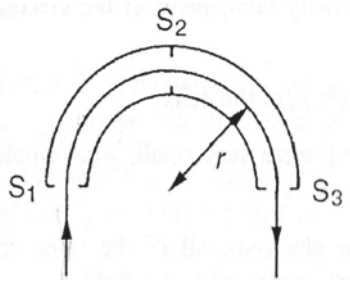
23 Two long parallel vertical wires X and Y carry currents of 3 A and 5 A respectively. The current in wire X flows upward and the force per unit length experienced by wire X is 3×10^{-5} N m^{-1} to the right as shown below.



What is the direction of the current in wire Y and the force per unit length experienced by wire Y?

	direction of current	force per unit length / N m^{-1}
A	upward	3×10^{-5}
B	downward	3×10^{-5}
C	upward	5×10^{-5}
D	downward	5×10^{-5}

24 The figure below shows an arrangement of two metallic half-cylinders with a common axis with a number of slits S that define a semi-circular path of radius *r*. The whole arrangement is enclosed in a vacuum vessel. The outer half-cylinder is at a positive potential with respect to the inner one so that a constant radial electric field is maintained between them. A collimated beam of singly charged positive ions is injected at S_1.



The incident beam contains ions of different masses and speeds.

Which property is identical for the ions in the beam emerging at S_3?

A mass

B speed

C kinetic energy

D momentum

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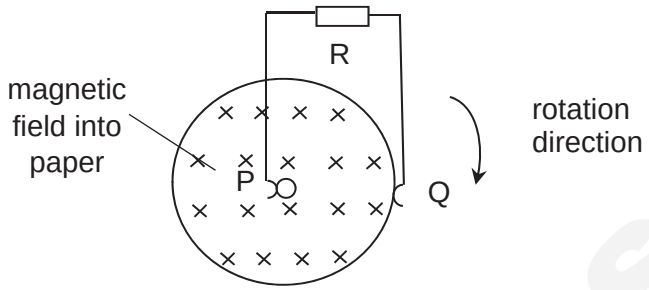
25 A copper disc rotates uniformly between the pole-pieces of a powerful magnet (not shown in figure) in a clockwise direction. P and Q are metallic brushes making contact with the axle and the edge of the disc respectively.



Which of the following statements is correct?

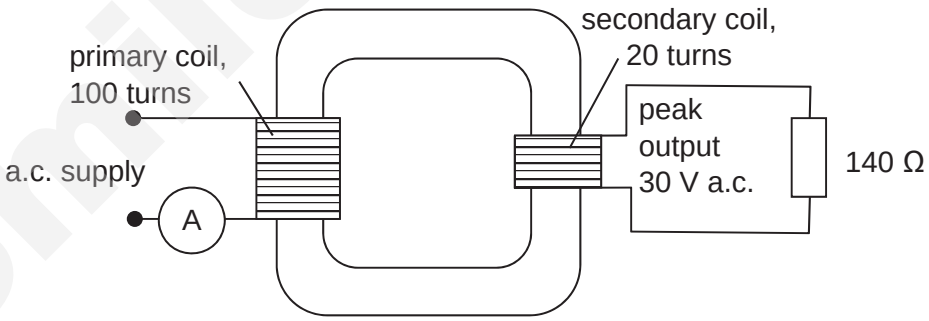
A No current flows through R because there is no change in flux linking the disc.

B No current flows through R because it is part of an open circuit.

C A steady current flows from P, through R, to Q.

D A steady current flows from Q, through R, to P.

26 A 100% efficient transformer is connected as shown to a sinusoidal a.c. supply.



What is the reading on the ammeter?

A 0.030 A **B** 0.043 A **C** 0.76 A **D** 1.1 A

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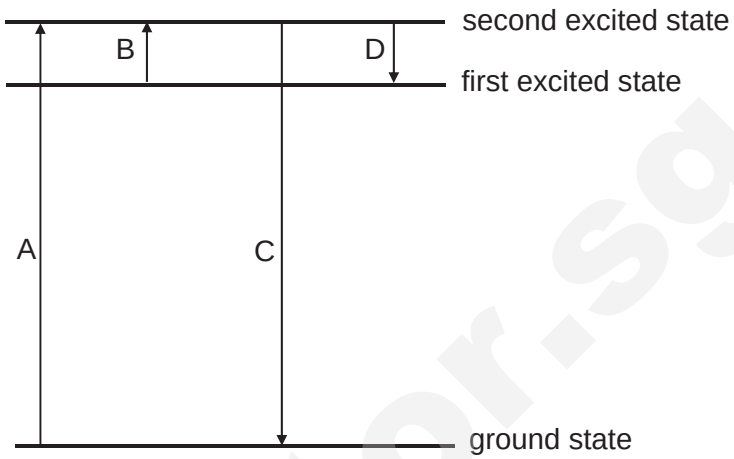
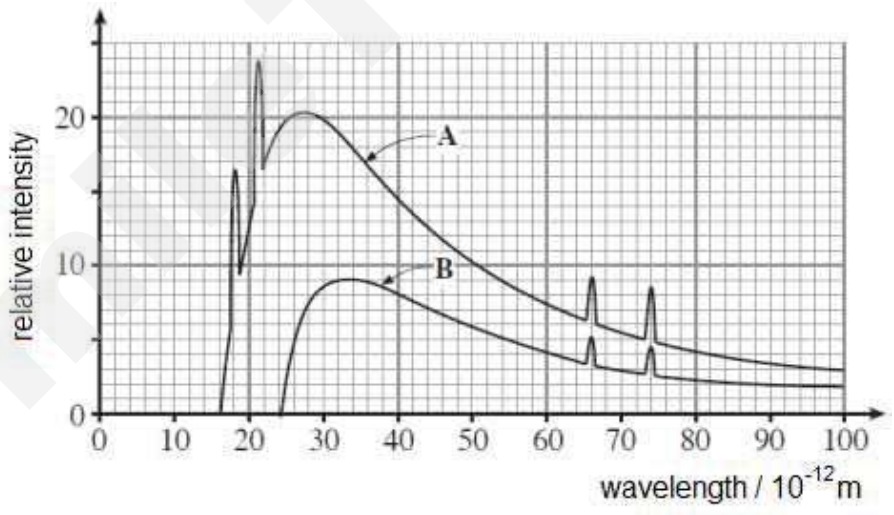
27 The diagram below shows some possible electron transitions between three principal energy levels in the hydrogen atom.

Which transition is associated with the absorption of a photon of the longest wavelength?



28 The diagram shows two spectra of X-rays from an X-ray tube.



What can be deduced from the graph?

A the accelerating voltage to produce spectrum B is higher than spectrum A
B spectrum B has a continuous spectrum but no discrete spectrum
C the target material to produce spectrum A has a higher mass number
D the same target material is used to produce spectra A and B

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29 High energy alpha particles can transform Nitrogen-14 to Oxygen-17.
The equation for this nuclear reaction is

$$^{14}_{7}\mathrm{N} + ^{4}_{2}\mathrm{He} \rightarrow ^{17}_{8}\mathrm{O} + ^{1}_{1}\mathrm{H}$$

The sum of the rest masses of the nitrogen and helium nuclei is 18.006 u.
The sum of the rest masses of the oxygen and hydrogen nuclei is 18.007 u.
The energy equivalent of 0.001 u is 1 MeV.

What do the data show?

A Mass of 0.001 u has been converted into 1 MeV of energy.

B The kinetic energy of the reactants exceeds the kinetic energy of the products by 1 MeV.

C The kinetic energy of the products exceeds the kinetic energy of the reactants by 1 MeV.

D The reactants had only 1 MeV of kinetic energy and all of this was converted into mass.

30 The nuclide $^{90}_{38}\mathrm{Sr}$ is a β-emitter of half-life 28 years.

If a $^{90}_{38}\mathrm{Sr}$ source emits many β-particles in one second today, how long will it take to emit the same number of β-particles in the year 2073?

A 0.25 s **B** 0.5 s **C** 2 s **D** 4 s

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2017 TJC H2 Physics Prelim Paper 1 Solutions

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D	**A**	**C**	**D**	**C**	**B**	**B**	**D**	**D**	**D**	**C**	**C**	**B**	**C**	**A**
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	**C**	**A**	**B**	**A**	**B**	**C**	**A**	**C**	**D**	**A**	**B**	**D**	**B**	**D**

1 **D** M_{min} = 15 x (0.98 g) = 14.7 g

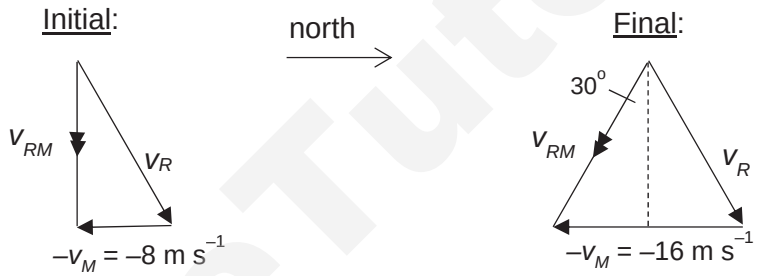
M_{max} = 16 x (1.02 g) = 16.3 g

$\langle M \rangle$ = 15.5 g

$\Delta M = (M_{max} - M_{min})/2$ = 0.8 g

Thus M = 15.5 ± 0.8 g

2 **A** Relative velocity v_{RM} of rain with respect to man is $v_{RM} = v_R - v_M$, a vector subtraction. v_R is the velocity of the rain (which stays the same) and v_M is the velocity of the man.



3 **C** Average velocity = (change in displacement) /(time taken)
= (AC) /(T) = 2L /T

4 **D** Let T be the time interval between the drops falling from the tap. The first drop takes 2T (from t = 0 to t = 2T) to fall 5.00 m to ground, thus we have:

$5.00 = \frac{1}{2} g(2T)^2$

The 2nd drop would have fallen in a time of T (from $t = T$ to $t = 2T$) a distance

$y = \frac{1}{2} g(T)^2$

Solving, y = 1.25 m. Thus distance of 2nd drop from ground = 5.00 – 1.25 = 3.75 m

5 **C** Angle that the string makes with vertical is 30°.

$$\cos 30^o = \frac{W}{T} = \frac{\sqrt{3}}{2} \Rightarrow T = \frac{2W}{\sqrt{3}}$$

6 **B** Constant velocity downwards gives:

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↑+: $T - mg = 0 \Rightarrow ke_o - mg = 0 \Rightarrow ke_o = mg$ .....(1)

Slowing down, velocity downwards $\Rightarrow$ acceleration points upwards:
↑+: $T_1 - mg = ma \Rightarrow ke_1 - ke_o = ma \Rightarrow k(e_1 - e_o) = ma$ .....(2)

$$(2)/(1) \Rightarrow \frac{(e_1 - e_o)}{e_o} = \frac{a}{g} \Rightarrow (e_1 - e_o) = \frac{e_o a}{g} = \frac{(50.0 - 25.0)(2.0)}{10.0} = 5.0 \text{ cm}$$

7 **B** Answer B is not possible as the two vehicles that came to a stop at the same time cannot continue their motion again with their individual same initial momentum as that would imply the trucks had passed through each other.

8 **D**
$$\eta = \frac{P_{out}}{P_{in}} = \frac{mgh/t}{P_{in}} = \frac{mgv}{P_{in}} = ... = 76\%$$

9 **D**

considering mass 3 :
$T_3 = F_C = m(3r)\omega^2$
considering mass 2 :
$T_2 - T_3 = (m)(2r)\omega^2$
$T_2 - 3mr\omega^2 = 2mr\omega^2$
$T_2 = 5mr\omega^2$
considering mass 1 :
$T_1 - T_2 = (m)(r)\omega^2$
$T_1 - 5mr\omega^2 = mr\omega^2$
$T_1 = 6mr\omega^2$

$T_1 : T_2 : T_3 = 6 : 5 : 3$

Alternatively:
Consider all 3 masses as 1 system:
$T_1 = (3m)(2r)\omega^2$

Consider mass 2 and mass 3 as 1 system:
$T_2 = (2m)(2.5r)\omega^2$

Consider mass 3 alone:
$T_3 = (m)(3r)\omega^2$

$T_1 : T_2 : T_3 = 6:5:3$

10 **D**
$$E_i = E_f$$
$$\frac{1}{2}mv_e^2 + \left(-\frac{GMm}{R}\right) = 0 + 0$$
$$v_e = \sqrt{\frac{2GM}{R}} \alpha \sqrt{\frac{M}{R}}$$

11 **C** $Q = C\,\Delta\theta \propto C$
Since $\Delta\theta$ is same for both blocks,
$C_{Cu} > C_{Al} \Rightarrow Q_{Cu} > Q_{Al}$

12 **C** Using First law Of Thermodynamics,
$\Delta U = Q + W$
$U_B - U_A = Q + W$

Expansion $\Rightarrow W$ negative
$T_B > T_A \Rightarrow U_B > U_A$

13 **B** $\Delta U = W_{on} + Q_{in}$

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Process AB: Isochoric $\Rightarrow W_{on} = 0$. $\Delta T>0 \Rightarrow \Delta U>0$. Thus, $Q_{in}>0$.
Process BC: Isothermal $\Rightarrow \Delta T=0 \Rightarrow \Delta U=0$. Gas expands $\Rightarrow W_{on} < 0$. Thus, $Q_{in}>0$.
Process CA: Isobaric. $\Delta T<0 \Rightarrow \Delta U<0$. Gas contracts $\Rightarrow W_{on} > 0$. Thus, $Q_{in}<0$.
Process ABCA: Cyclic $\Rightarrow \Delta T=0 \Rightarrow \Delta U=0$. net $W_{on} < 0$ (deduced from equivalent *p-V* graph) $\Rightarrow$ net $Q_{in}>0$.

14 C For the grain of sand,

↑+: At $x = x_o$, $a = -g$
$N - mg = m(-g)$
$N = 0$

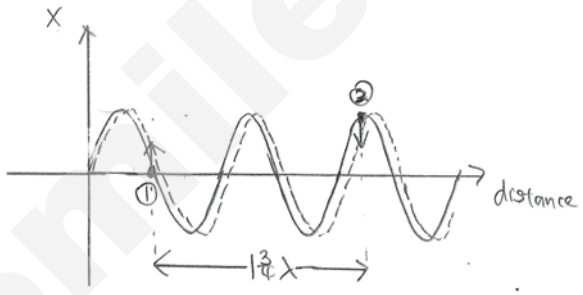
At $x = 0$, $a = 0$
$N - mg = m(0)$
$N = mg$

At $x = -x_o$, the acceleration of the platform changes to an upwards direction, i.e. $a = +g$
$N - mg = m(+g)$
$N = 2mg$

15 A $v = f\lambda$

$v = \dfrac{\lambda}{T} \Rightarrow \lambda = 330(500\times10^{-6}) = 0.165\text{ m}$

A distance of 0.289 m $\Rightarrow$ 0.289/0.165 = 1 ¾ λ further away from source



16 B $T = 1/f$ = 1/250 = 4 ms
∴after 5 ms = 1.25 cycles

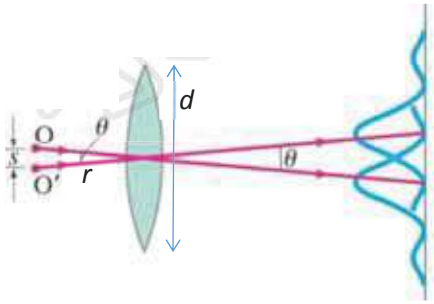
17 C Rayleigh's criterion:

$\sin\theta = \dfrac{\lambda}{d} \approx \theta$ for small θ

$\theta = \dfrac{s}{r} = \dfrac{\lambda}{d}$

$\dfrac{1.0\times10^{12}}{1.0\times10^{15}} = \dfrac{0.030}{d}$

$d = 30\text{ m}$



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18 A Electric field strength is the negative of the electric potential gradient which is the change in electric potential per unit distance. Hence $E_X > E_Y$
Direction of field always in direction of decreasing potentials.

19 B At x = 5.0 x 10^{-2} m, resultant field $E = E_A + E_B$

$1.8 \times 10^3 = \frac{Q_A}{4\pi\varepsilon_o x^2} + E_B$ where Q_A = +2.0 x 10^{-10} C

$1.8 \times 10^3 = 720 + E_B \Rightarrow E_B = +1.08 \times 10^3$ Vm^{-1}

Since E_B is positive, it is in the increasing x direction and points towards sphere B. Thus Q_B is a negative charge.

If a candidate obtained $E_B = 1.76 \times 10^3$ Vm^{-1}, the formula $V = \frac{Q}{4\pi\varepsilon_o x^2}$ must have be incorrectly used instead of that for E field.

20 A

21 B Energy produced by cell = $\varepsilon I t$ = 18 J
ε x 0.025 x 80 =18 $\Rightarrow \varepsilon$ = 9.0 V

Energy dissipated in the cell = $I^2 r t$ = 18 – 11 – 4 = 3 J
0.025^2 x r x 80 = 3
r = 60 Ω

22 C P.d. across XY is reduced. Hence potential gradient of wire XY is smaller. For the same p.d. across XP (= e.m.f. of cell B), the balance length increases.

For **A**, p.d. across XY is unchanged.
For **B**, terminal p.d. across cell B is reduced. Hence balance length is smaller.
For **D**, presence of 1.0 Ω resistor does not affect balance length since no current flows through cell B.

23 A Applying Newton's third law, force on Y is towards X. Force per unit length experienced by Y is the same as that experienced by X and current in Y flows in the same direction as that in X.

24 C electric force on positive ion provides centripetal force for it to move in a circular path.
$eE = mv^2/r \Rightarrow mv^2 = eEr$
Since ions which emerge from S_3 underwent the same circular path of radius r, and e, E are constants, these ions have the same kinetic energy.

25 D Use Fleming's Right Hand Rule.

26 A

$$I_s = \frac{V_s}{R} = \frac{\frac{30}{\sqrt{2}}}{140} = 0.151 \text{ A}$$

$$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{20}{100}$$

$$\frac{I_P}{0.151} = \frac{20}{100} \Rightarrow I_P = 0.0302 \text{ A}$$

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27 **B** For absorption of a photon to take place, the energy transition is from a lower energy level to a higher energy level. For absorption of a photon with highest wavelength, the difference between the 2 energy levels is the smallest. i.e. $\Delta E = \frac{hc}{\lambda}$.

28 **D** Same target atom since the L_α and L_β are the same wavelengths showing the same set of energy levels. The K peaks are missing for spectrum B as the incident electrons do not have sufficient energy to reach to the K shells.

29 **B** For reaction to proceed, the total mass (or energy) of the reactants must exceed the total mass (or energy) of the products by 0.001 u (or 1 MeV).

30 **D** $A/A_o = (½)^n$ where $n = t/t_{1/2}$
For same number of β-particles to be emitted now and in 2073 (56 years later),
$A_o\, t_o = A\, t$
$t = (A_o/A) \times 1 = 2^2 \times 1 = 4$ s

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TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

CANDIDATE NAME			
CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

12 September 2017
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total	

This document consists of **21** printed pages.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1} $(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2} at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^{\,2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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1 To investigate how well a basketball can bounce after hitting a hard surface, a student drops the basketball from a fixed height h_1 and measures the rebound height h_2. The experimental setup is shown in Fig. 1.1.

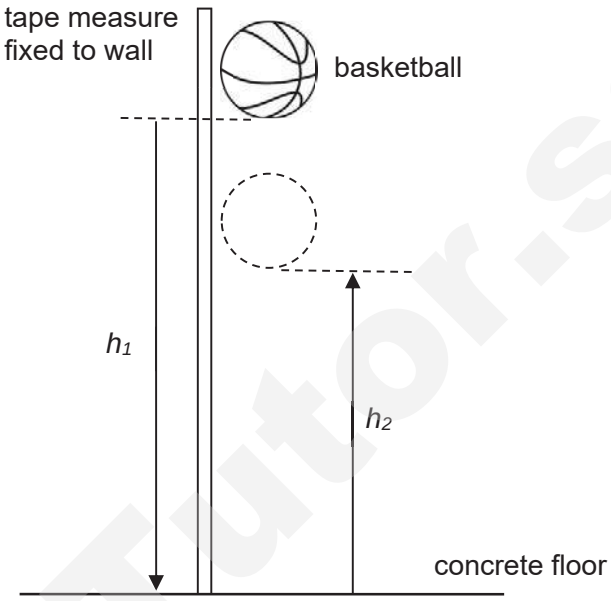

Fig. 1.1

Theory suggests that h_1 and h_2 are related by the expression

$$h_2 = e^2 h_1$$

where e is a constant known as the *coefficient of restitution*.

The following results are obtained by the student:

$h_1 = 200 \pm 1$ cm
$h_2 = 135 \pm 5$ cm

(a) Suggest why the uncertainty for h_2 is larger than that for h_1.

.....

.....

..... [1]

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(b) **(i)** Calculate the value of e.

e = ... [1]

(ii) Calculate the actual uncertainty in e.

actual uncertainty in e = ... [2]

(iii) State the value of e and its actual uncertainty to the appropriate number of significant figures.

e = ... ± ..... [1]

(c) The student decides to obtain further sets of readings for different h_1 and h_2. A graph of h_2 against h_1 is plotted, as shown in Fig. 1.2. From the graph, the gradient of the best-fit line is determined and the value of e^2 and hence e is obtained.

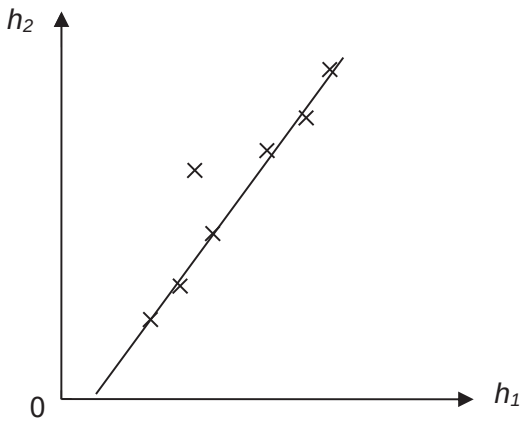

Fig. 1.2

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Suggest two advantages that plotting this graph might provide, compared to just using a single set of data for h_1 and h_2 to compute e.

1. .....

.....

2. .....

.....

[2]

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2 A train passenger is running at a maximum velocity of 3.0 m s^{-1} to catch a train. At time t = 0 s, when the passenger is at a distance d from the nearest entrance of the train, the train starts from rest with a constant acceleration of 0.30 m s^{-2} away from the passenger. The passenger just catches the train to jump into the nearest entrance.

(a) Fig. 2.1 shows the variation with time t of the displacement of the nearest entrance of the train.

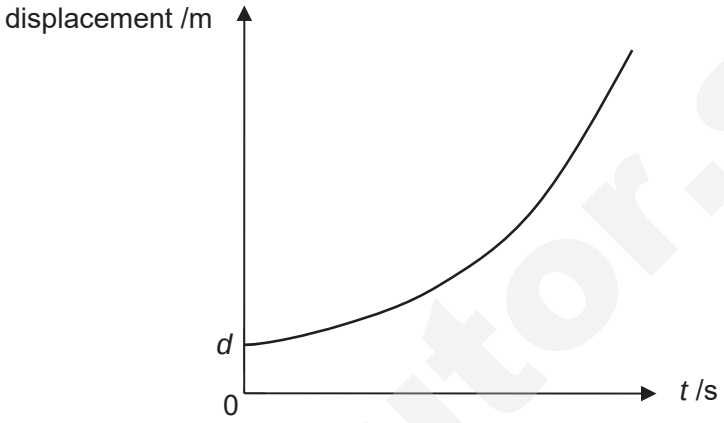

Fig. 2.1

Sketch on Fig. 2.1 a line showing the variation with time t of the displacement of the passenger. Label the line P. [1]

(b) Determine how long it will take the passenger to catch the train.

time = ... s [3]

(c) Hence calculate the distance d.

d = ... m [3]

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3 **(a)** Fig. 3.1 shows an arrangement which can be used to determine the speed of sound in air.

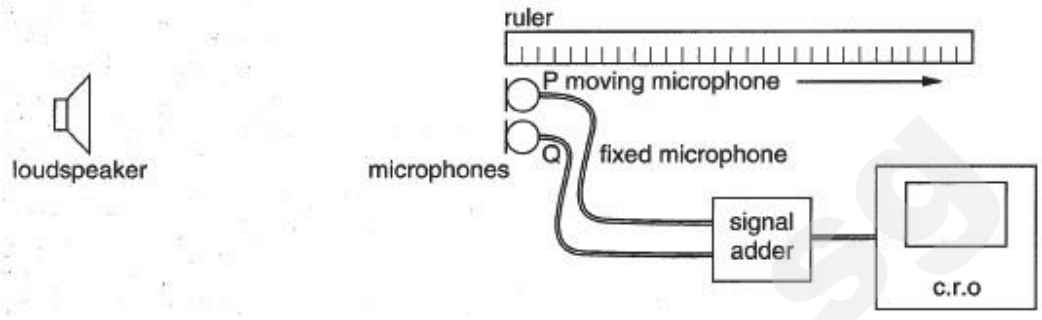

Fig. 3.1

The loudspeaker emits a sinusoidal sound wave. The electrical signals from the two microphones P and Q are added together in the electronic "signal adder" and the resultant signal is displayed on the cathode-ray oscilloscope (c.r.o.) screen. This process may be regarded as equivalent to the superposition of the waves. Microphone Q is **fixed** and microphone P is **slowly moved** back along the edge of the ruler.

(i) Fig. 3.2 shows the appearance of the trace on the c.r.o. when both microphones are at the left hand end of the ruler, that is, the same distance from the loudspeaker.

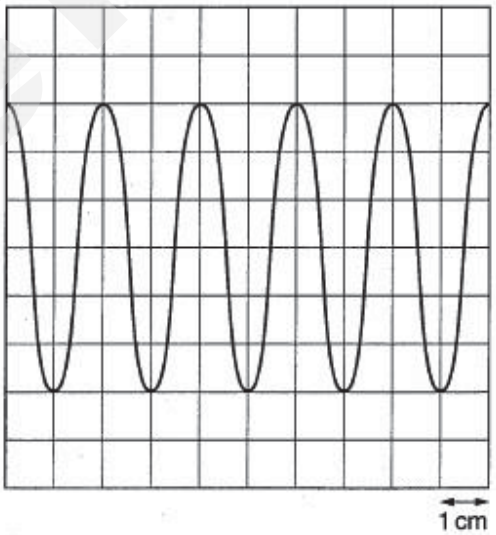

Fig. 3.2

The time-base setting of the c.r.o is 0.2 ms cm^{-1}. Determine the frequency of the sound wave.

frequency = ... Hz [2]

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(ii) As P is moved slowly along the edge of the ruler, the amplitude of the trace is seen to decrease, then increase, then decrease and so on.
Explain

1. why the amplitude is a maximum when P and Q are at the left hand of the ruler,

.....

.....

..... [2]

2. why the amplitude of the trace varies.

.....

.....

..... [2]

(iii) The first minimum of the amplitude occurs when P is at a distance of 6.8 cm from the left hand end of the ruler. Determine

1. the wavelength of the sound.

wavelength = ... m [2]

2. the speed of the sound in air.

speed = ... $m\ s^{-1}$ [1]

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(b) A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 3.3.

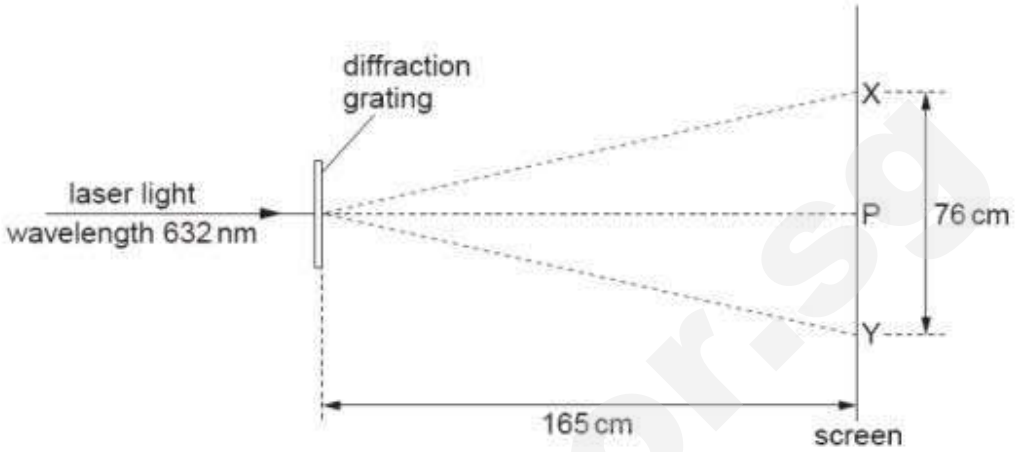

Fig. 3.3

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y. X and Y are separated by a distance of 76 cm.

Calculate the number of lines per millimetre on the grating.

number of lines per millimetre = ... [2]

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4 A certain electric hotplate, designed to operate on a 250 V supply, has two coils of nichrome wire of resistivity $9.8 \times 10^{-7}\ \Omega$ m. Each coil consists of 16 m of wire of cross-sectional area 0.20 mm^2.

(a) For one of the coils, calculate

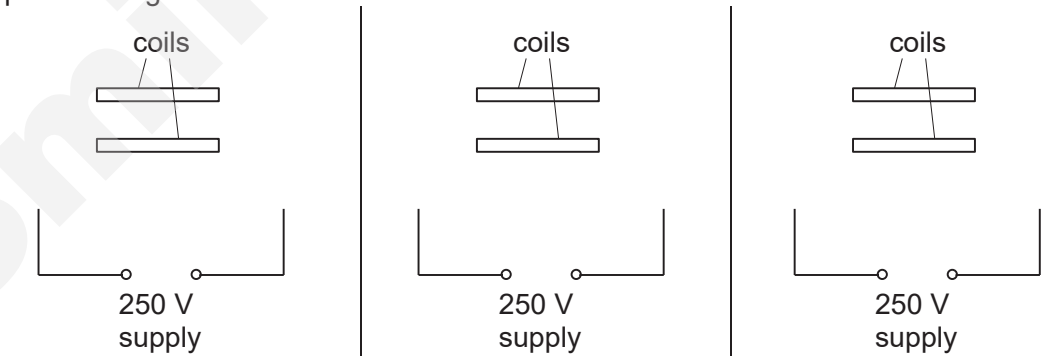
(i) its resistance,

resistance = ... Ω [2]

(ii) the power dissipated when a 250 V supply is connected across the coil, assuming its resistance does not change with temperature.

power dissipated = ... W [2]

(b) Complete the circuits in Fig. 4.1 to show how the coils may be arranged so that the hotplate may be made to operate at three different powers. In each case calculate the power rating.



power rating = _____ W | power rating = _____ W | power rating = _____ W

Fig. 4.1 [5]

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(c) The hotplate is connected to the 250 V supply by means of cable of resistance 3.0 Ω. Calculate the power loss in the connecting cable when the hotplate is being used on its **middle power rating** in **(b)**.

.....

power loss = ... W [3]

5 (a) (i) Draw a clear fully labelled diagram to illustrate the direction of the force *F* acting on a long, straight copper wire carrying a current I at an angle θ to a uniform magnetic field of flux density *B*.

[2]

(ii) Write down the expression for the force per unit length of the wire in **(a)(i)** in terms of *B*, I and θ.

force per unit length of wire = ... [1]

(iii) Hence define the *tesla*.

.....

.....

[1]

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(b) Fig. 5.1 shows a moving-coil loudspeaker.

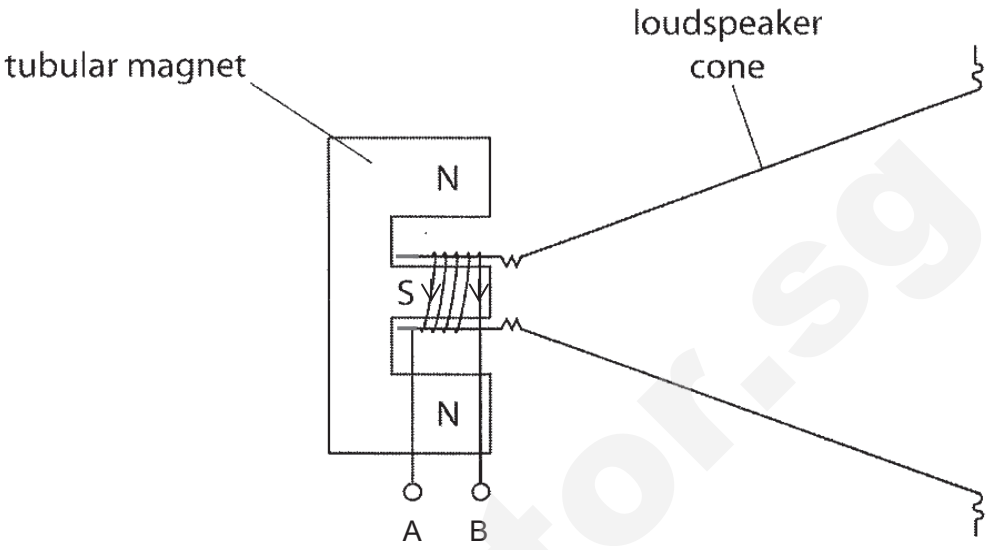

Fig. 5.1

The tubular magnet provides a radial magnetic field between the poles. A coil of copper wire surrounds the south pole of the tubular magnet. A current of 25 mA is passed through the coil from terminal A to terminal B. Each turn of the copper wire experiences a constant magnetic field of flux density 28 mT. The copper coil has a mean diameter of 16.4 mm and 250 turns.

(i) State and explain the direction of the force experienced by the coil of wire.

.....

.....

.....

..... [2]

(ii) Calculate the force experienced by the coil of wire.

force = ... N [3]

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6 **(a)** By reference to the photoelectric effect, explain

(i) what is meant by *work function energy*,

.....

.....

..... [2]

(ii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energy up to a maximum value.

.....

.....

..... [2]

(b) Electromagnetic radiation of frequency f is incident on a metal surface. The variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from the surface is shown in Fig. 6.1.

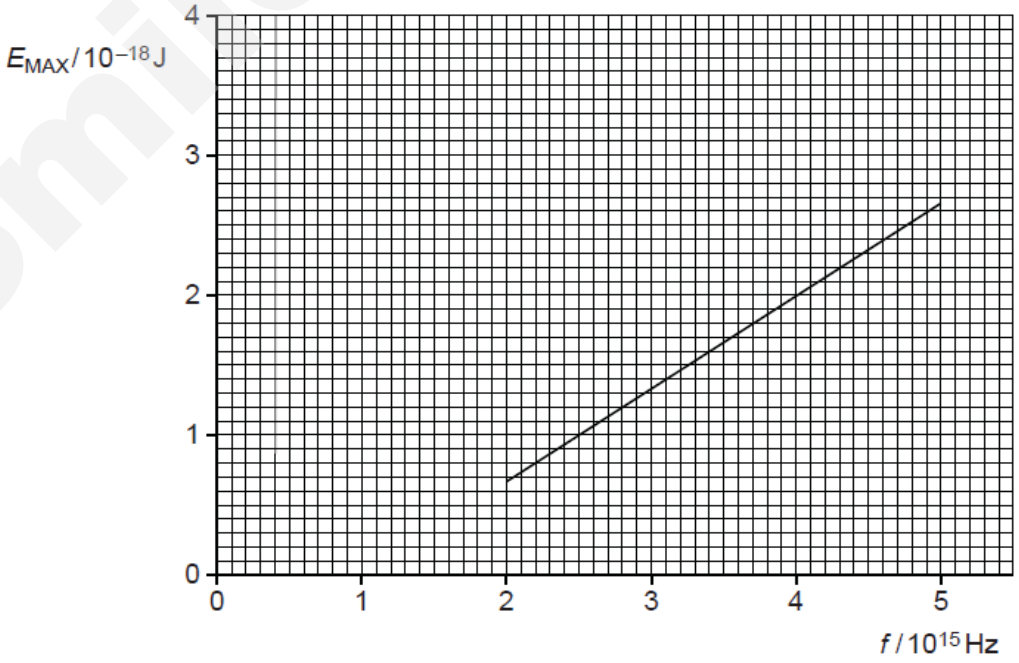

Fig. 6.1

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(i) Use Fig. 6.1 to determine the work function energy of the metal surface.

work function energy = ... J [3]

(ii) A second metal has a greater work function energy than that in **(i)**.
On Fig. 6.1, draw a line to show the variation with f of E_{MAX} for this metal. [2]

(iii) Explain why the graphs in **(i)** and **(ii)** do not depend on the intensity of the incident radiation.

.....

.....

..... [2]

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7 Fig. 7.1 shows the important features of the apparatus used by Millikan to measure the electron charge by observations on charged oil droplets.

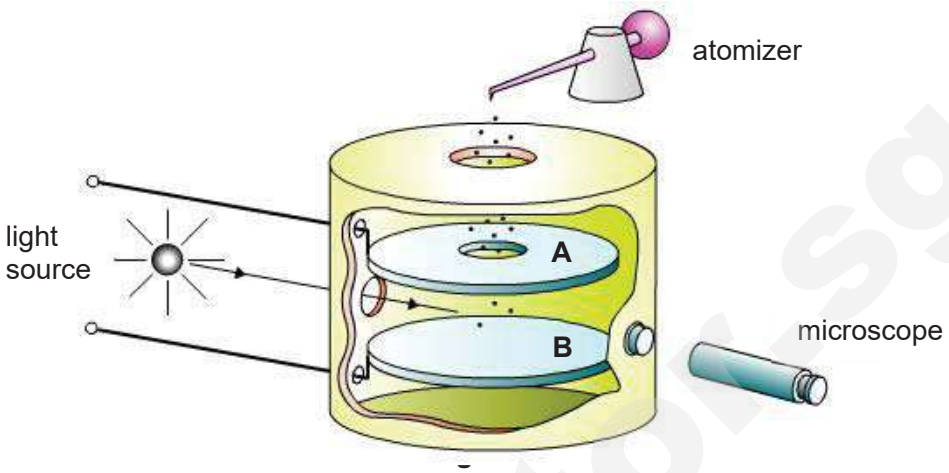

Fig. 7.1

The apparatus consists of a pair of horizontal metal plates A and B separated by a distance *d*.

The microscope is focused on the illuminated space under the hole through which oil droplets can enter. A potential difference is applied across the plates.

A squeeze on the atomizer causes a shower of droplets to be seen. Most of these droplets are uncharged and drift downwards through the air with their terminal velocities. A few can be seen to move upwards. These are the ones which have acquired a negative charge and therefore experience an upward electrical force on them.

The potential difference between the plates is adjusted to keep a particular oil droplet stationary and its value *V* is measured.

(a) (i) Assuming that the oil droplet has a weight *W* and carries a charge *Q*, show that $Q = W\left(\frac{d}{V}\right)$ for the oil droplet to remain at rest, neglecting the upthrust of the air.

[1]

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(ii) State and explain which plate, A or B, is at higher potential.

.....

.....

..... [2]

(iii) Explain why it is reasonable to neglect the upthrust.

.....

..... [1]

(b) The weight of an oil droplet is found by timing its fall (with terminal speed) over a standard distance, when the potential difference across the plates is zero.
Fig. 7.2 shows the relationship between the weight W of oil droplets and the time T taken by the oil droplets to fall 1.00 mm in air.

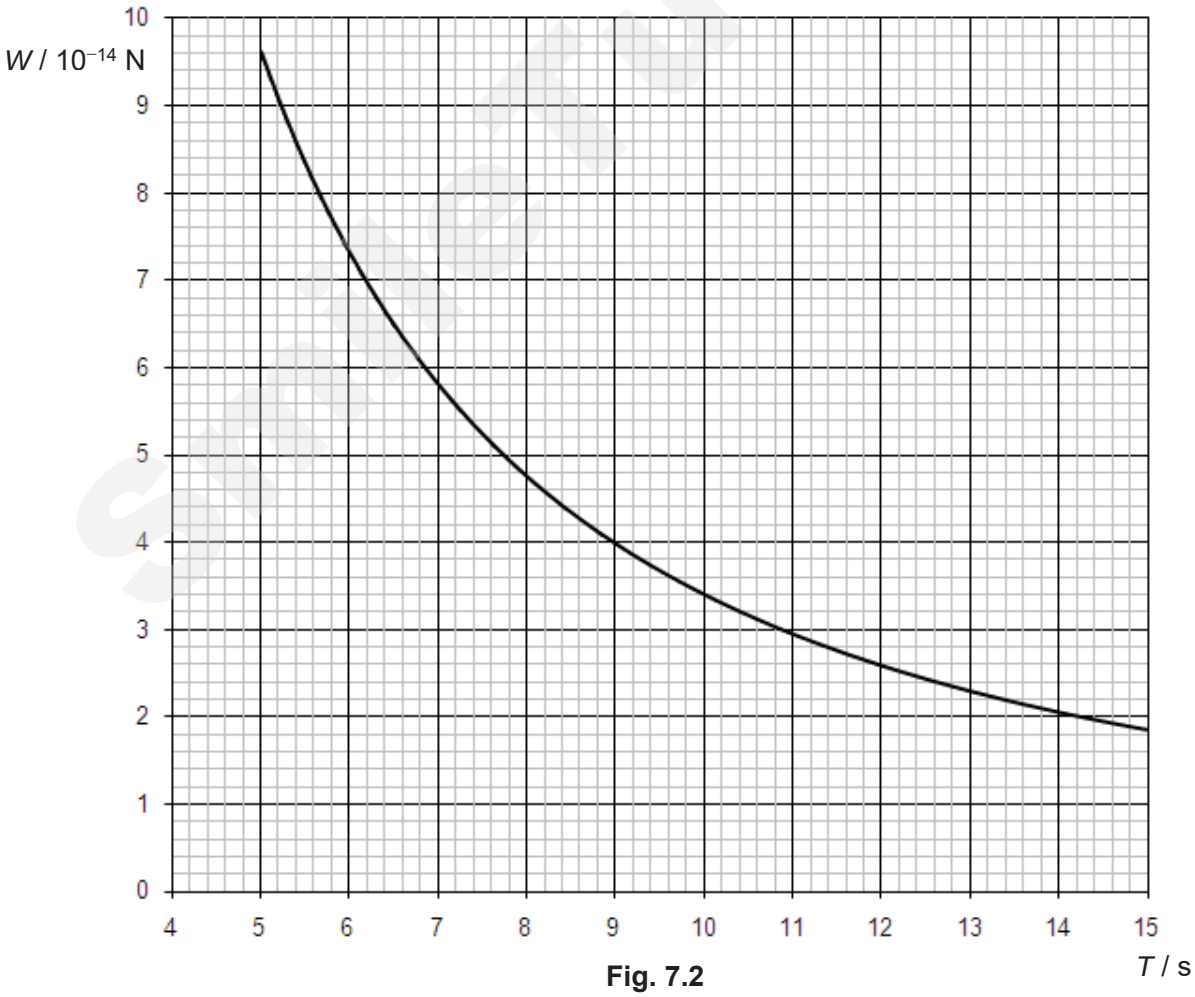

Fig. 7.2

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The results shown in Fig. 7.3 were obtained with a Millikan apparatus. For each oil droplet, the experimenter measured V across the plates (which were 4.42 mm apart) at which the droplet was observed to be stationary, and the time T for the droplet to fall 1.00 mm in air with terminal speed after switching off the potential difference.

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6		
820	6.9	5.9	3.18
395	6.2	7.0	7.83

Fig. 7.3

Complete Fig. 7.3. [2]

(c) It is suggested that the drag force F_D on a small sphere of radius r moving with speed v through a viscous fluid is given by

$$F_D = 6\pi\eta rv$$

where η is the coefficient of viscosity of the fluid.

If the coefficient of viscosity of air at room temperature is 1.8 x 10^{-5} kg m^{-1} s^{-1}, estimate the radius of the oil droplet for the first row of Fig. 7.3.

radius = ... m [3]

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(d) It is thought that, when the potential difference between the plates is zero, the weight W of an oil droplet varies with time T of its fall (with terminal speed over a standard distance) according to the equation

$$W = aT^b \quad \cdots(1)$$

where a and b are constants.

Some data from Fig. 7.2 are used to plot the graph of Fig. 7.4.

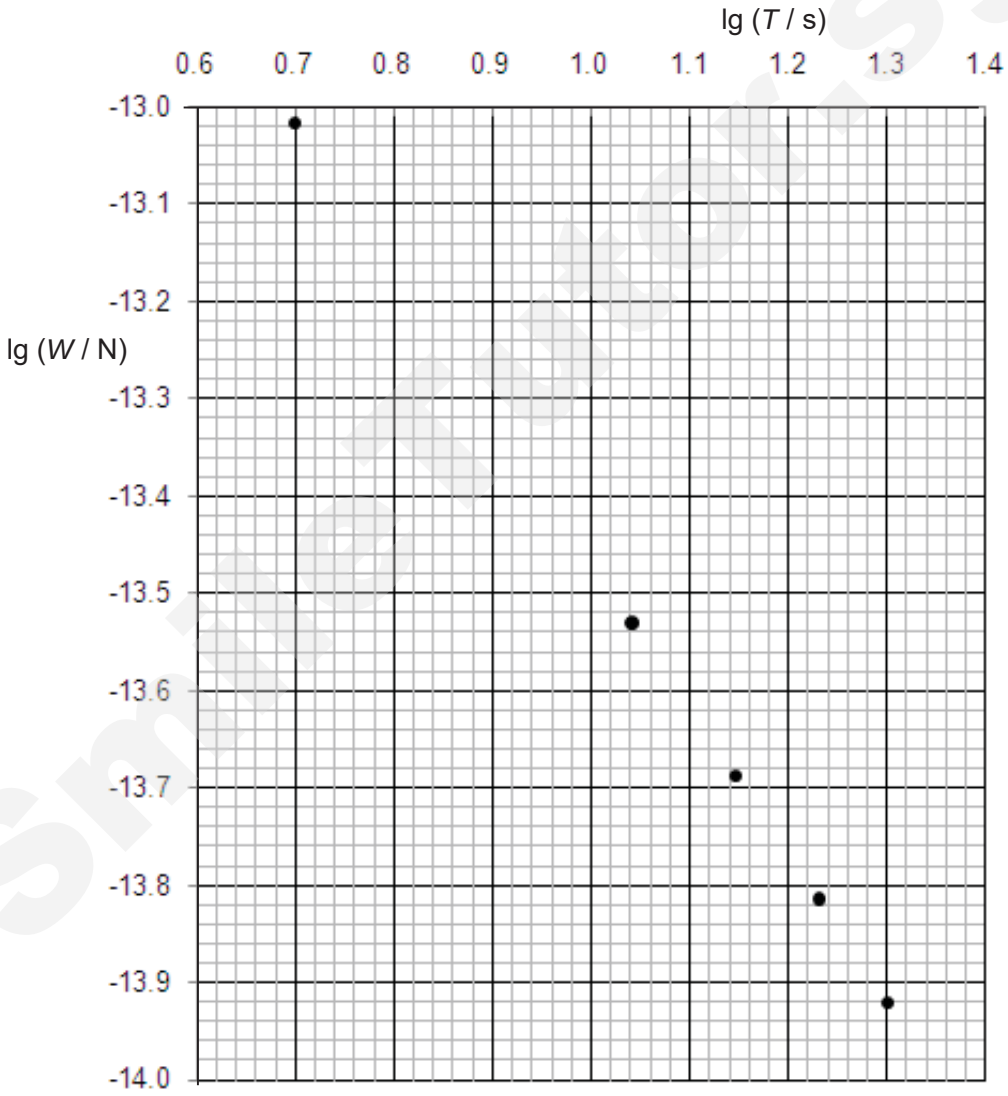

Fig. 7.4

(i) Use Fig. 7.2 to determine lg (W / N) for a time T of 8.0 s.

lg (W / N) = …….. [1]

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(ii) On Fig. 7.4,

1. plot the point corresponding to T = 8.0 s, [1]

2. draw the line of best fit for the points. [1]

(iii) Use the line drawn in **(d)(ii)** to determine the constant b in equation (1).

.....

b = ... [2]

(iv) Deduce, from your value of b in **(d)(iii)**, how the weight W of oil drop would depend on its terminal speed v.

[2]

(v) The density of the oil droplet is proportional to $\frac{1}{a^2}$, where a is the constant in equation (1).

A similar experiment is performed under the same conditions, but the oil used has a higher density.

On the axes of Fig. 7.4, sketch a graph to show a possible variation with lg T of lg W.

[1]

(e) The Millikan experiment is said to provide experimental evidence for the *quantisation of charge*. Explain what is meant by *quantisation of charge.*

.....

[1]

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(f) An early experimenter, working in non SI units, obtained the following six values for the magnitudes of the charges on small oil drops.

$Q/10^{-9}$ units	6.86	4.44	8.37	5.39	1.97	2.96

Use these results to find the magnitude of the basic electronic charge as measured in these units.

basic electronic charge = ……units [3]

(g) The diameters of the droplets used by Millikan were of the order of 10^{-6} m (about two wavelengths of visible light). He deduced their masses by measuring their speeds and using data on the viscosity of air, similar to the method described above.

Suggest a reason why Millikan did not measure the diameter of an oil droplet using a microscope and then calculate its mass from the measured diameter and the known density of oil.

.....

.....

.....

..... [2]

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Solutions to 2017 TJC H2 Physics Prelim Paper 2

1 (a) The basketball started at rest at the height of h_1, thus the uncertainty for its position when measuring h_1 is small. B1

It is however difficult to determine when the ball has come to rest on its rebound, thus the final position of the ball and hence the height h_2 has a larger uncertainty.

-Other possible suggestion: ball might not bounce perpendicularly to floor, thus the measured rebound height might not be accurate, and has a larger uncertainty.

-note that the measurement of h_2 involves the determination of 2 position readings, that at the start and also the maximum height position. h_2 is also required to be perpendicular to the ground. Thus any factor that affects the reading of the 2 positions, or affects the perpendicular bounce of the ball would add to the uncertainty.

(b) (i) $$e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{135}{200}} = 0.822$$ A1

(ii) $$\frac{\Delta e}{e} = \frac{1}{2}\left(\frac{\Delta h_2}{h_2} + \frac{\Delta h_1}{h_1}\right)$$ C1

$$\Delta e = \frac{1}{2}\left(\frac{5}{135} + \frac{1}{200}\right)(0.822) = 0.02$$ A1

(iii) $e = 0.82 \pm 0.02$ A1

(c) Any 2 of the following points: B2

- The graph provides a confirmation of the linear relationship between h_1 and h_2.
- The best-fit line reduces the effects of random errors in the reading of each data point.
- The graph uncovers outlying data points, which could then be further investigated.
- The graph did not pass through the origin, as predicted by the given equation. This could indicate the presence of systematic error in the experiment.

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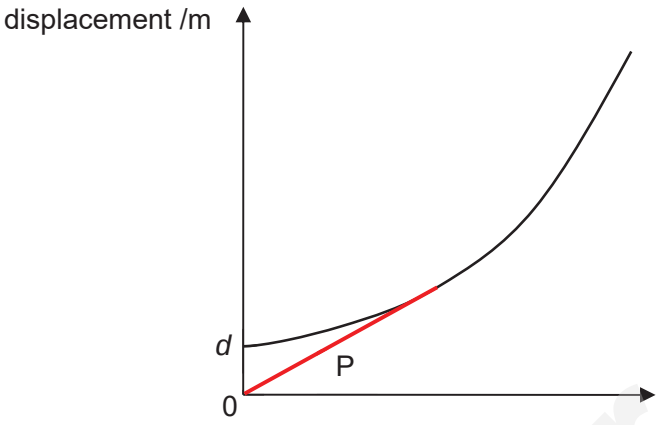
2 **(a)**



B1

P is a straight line just touching the bottom of the displacement-time graph of the train. The straight line should not extend beyond the point of contact as the passenger would have boarded the train.

(b) When the passenger 'just' catches the train, $v_P = v_T$ C1
$3.0 = (0) + (0.30)t$ C1
$t = 10$ s A1

(c) $s_P = d + s_T$ C1
$(3.0)(10) = d + [(0)(10) + ½ (0.30)(10)^2]$ C1
$d = 15$ m A1

3 **(a)(i)** One cycle is represented by 2 cm.
Thus period = $2 \times 0.2 \times 10^{-3} = 4.0 \times 10^{-4}$ s C1
$f = 1/T = 1/(4.0 \times 10^{-4}) = 2500$ Hz A1

(ii)1. P and Q are the same distance from speaker, thus the sound waves arrive in phase/zero path difference. B1
Constructive interference occurs. B1

(ii)2. As P is moved, the path difference changes. B1
Minima when P moves odd number of ½ wavelength, and maxima if P moves whole number of wavelengths. B1
OR Phase difference of waves arriving at P and Q changes; minima when waves meet out of phase & maxima when waves meet in phase.

(iii)1. First minimum corresponds to ½ λ path difference. C1
Wavelength = $2 \times 6.8 = 13.6$ cm = 0.136 m A1

(iii)2. $v = f\lambda = 2500\ (0.136) = 340$ m s^{-1} A1

(b) $\tan \theta = 38/165$ M1
$\theta = 12.99°$
$d \sin \theta = \lambda$
$d = 2.82 \times 10^{-6}$ m
no of lines per mm = $1/d = 355$ A1

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4 (a) (i)

$$R = \frac{\rho L}{A} = \frac{9.8 \times 10^{-7} \times 16}{0.20 \times 10^{-6}}$$

= 78.4 Ω

C1
A1

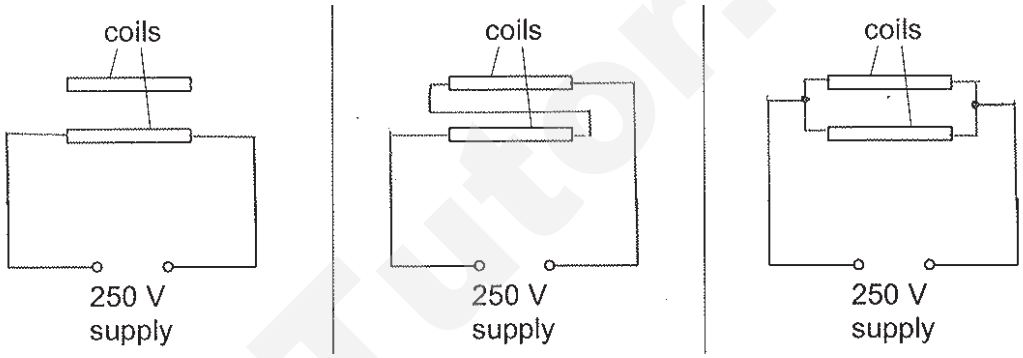
(ii)

$$P = \frac{V^2}{R} = \frac{250^2}{78.4}$$

= 797 W

C1
A1

(b)



power rating = 797 W | power rating = 399 W | power rating = 1590 W

B1 - each correct circuit diagram
A1 - correct power rating for series
A1 - correct power rating for parallel arrangement
-1 mark if power rating for one coil is not given

(c)

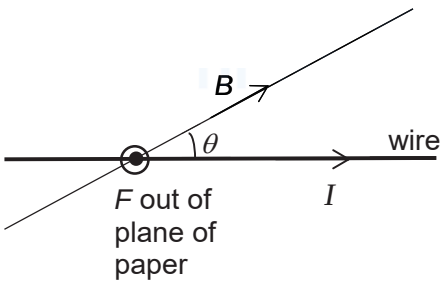
$$P_{loss} = I^2 r = \left(\frac{250}{78.4 + 3.0}\right)^2 \text{X } 3.0$$

C2

= 28.3 W

A1

5 (a) (i)



use Fleming's left-hand rule to determine correct direction of *F* M1

diagram showing clearly I at angle θ to *B*; *F* at right angles to the plane

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containing B and I A1

(ii) force per unit length of wire = $B\,I\,\sin\theta$ A1

(iii) The tesla is the uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 A, causes a force per unit length of 1 N m^{-1} to act on the wire. B1

(b) (i) consider top part of coil: I in wire flows out of page and B points down.
or consider bottom part of coil: I in wire flows into page and B points up. M1
(From Fleming's left-hand rule) force on coil points to the right. A1

(ii) $F = B\,I\,L\,(\sin\theta) \times N$
$= 28 \times 10^{-3} \times 25 \times 10^{-3} \times (\pi \times 16.4 \times 10^{-3}) \times 250$ C2
$= 9.0 \times 10^{-3}$ N (2 or 3 s.f.) A1

6 (a) (i) minimum photon energy B1
to remove an electron from the metal surface B1

(ii) Either maximum kinetic energy = photon energy – work function energy B1
Or electron has maximum kinetic energy when ejected from surface

Electrons within metal require energy to bring them to surface and so have lower energies than maximum KE. B1

(b) (i) threshold frequency = 1.00×10^{15} Hz (allow ± 0.05×10^{15} Hz) C1

work function energy = hf_0
$= 6.63 \times 10^{-34} \times 1.00 \times 10^{15}$ C1
$= 6.63 \times 10^{-19}$ J A1
(allow alternative approaches based on use of coordinates of points on the line)

(ii) straight line with same gradient M1
displaced to right A1

(iii) For the same incident frequency,
intensity determines number of photons arriving per unit time and B1
therefore it affects number of electrons emitted per unit time B1
(not maximum kinetic energy of electrons).

7 (a) (i) To remain at rest, net force = 0.

$$W = QE = Q\left(\frac{V}{d}\right) \Rightarrow Q = W\left(\frac{d}{V}\right)$$ A1

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(ii) Plate A is at higher potential. M1
Some negatively charged droplets drift upwards show that they experience upward electric force, against a downward electric field. A1

(iii) Density of air is negligible compared to density of oil at the same temperature. Thus upthrust which is the weight of the air displaced is negligible compared to the weight of oil. A1

(b)

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6	**5.1**	**4.80**
820	6.9	5.9	3.18
395	6.2	7.0	7.83

B1 Correct W
B1 Correct Q

-When T = 7.6 s, the curve cuts exactly at 5.1 when read to half the smallest square with little ambiguity. Thus only this value is accepted.

(c) At terminal speed, net force = 0.
$F_D = 6\pi r\eta v = 6\pi r\eta(D/t) = W$ C2
$\Rightarrow 6\pi r(1.8 \times 10^{-5})(0.001/11.2) = 2.9 \times 10^{-14}$
$\Rightarrow r = 9.57 \times 10^{-7}$ m A1

(d) **(i)** From Fig. 7.2, When T = 8.0 s, $W = 4.7 \times 10^{-14}$ N, A1
$\Rightarrow \lg W = -13.33$

(ii) 1. correct point plotted within half a square B1
2. best fit line drawn B1

(iii) $W = aT^b \Rightarrow \lg W = b\lg T + \lg a$ C1
b = gradient

$$= \frac{(-13.14)-(-13.86)}{0.78-1.26} = \frac{0.72}{-0.48} = -1.5$$ A1

(iv) $W = aT^{-1.5} = a\left(\frac{1}{T}\right)^{1.5}$ M1 A1

Terminal speed $v = \frac{d}{T}$

$\Rightarrow W = a\left(\frac{v}{d}\right)^{1.5} \propto v^{1.5}$ since a and d are constants

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(v) B1

Given $\rho_{oil} \propto \frac{1}{a^2}$. Higher oil density => smaller *a* and hence a more negative lg *a*. Thus the new graph is a straight line with same gradient (no change in *b*) but a more negative y-intercept.

(e) It means any electric charge is always an integer multiple of the basic electronic charge e. B1

(f) Divide all Q values by the smallest Q value of 1.97×10^{-9} units. C2
The approximate ratios are: 7/2, 9/4, 17/4, 11/4, 1, 3/2.

A1

Since charge cannot be quartered, basic electronic charge e must be $\frac{1}{4}(1.97 \times 10^{-9}) = 4.93 \times 10^{-10}$ units.

(g) Measuring oil drop diameter of order 10^{-6} m introduces a large percentage uncertainty. M1
Measuring their speed which is distance of order of 10^{-3} m covered in significant time will have a much lower percentage uncertainty and hence more accurate results A1

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TEMASEK JUNIOR COLLEGE

2017 Preliminary Examination
Higher 2

CANDIDATE NAME			
CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

14 September 2017
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This booklet consists of **24** printed pages.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1} $(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

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Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/^{o}$C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^{\,2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** State what is meant by the *internal energy* of a gas.

.....

..... [1]

(b) A cylindrical chamber contains an ideal gas as shown in Fig. 1.1. Initially, the piston, of mass 60.0 kg and circular cross-sectional area 3.00 x 10^{-2} m^2, is at a position such that the spring is unstretched at its natural length.

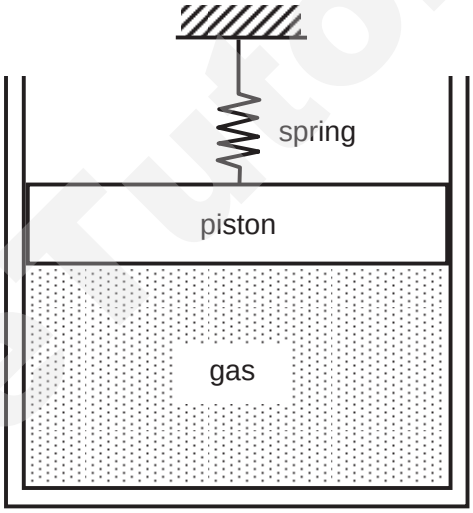

Fig. 1.1

When 200 J of heat is added to the gas, the piston moves gradually upwards to come to rest at a distance of 5.00 cm from its original position. Assume that there is no frictional force and the spring obeys Hooke's Law.
(Spring constant of spring = 50.0 kN m^{-1}, atmospheric pressure = 0.100 MPa.)

(i) Calculate the work done against gravity in raising the piston.

work done against gravity = ... J [1]

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(ii) Calculate the elastic potential energy stored in the spring when the piston is raised.

elastic potential energy = ... J [2]

(iii) Calculate the work done against atmospheric pressure in raising the piston.

work done against atmosphere = ... J [2]

(iv) Hence evaluate the change in internal energy of the gas at the end of its expansion.

change in internal energy = ... J [3]

(v) By considering all the forces acting on the piston when it is at its final position, calculate the final pressure of the gas.

final pressure of gas = ... Pa [3]

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2 **(a)** When a body is immersed fully in a fluid, it experiences an upthrust equal to the weight of fluid displaced.

(i) Explain what is meant by *upthrust.*

.....

.....[1]

(ii) Explain the origin of the upthrust.

.....

.....[1]

(iii) State two conditions for the upthrust to be independent of the depth of immersion.

.....

.....

.....[2]

(b) An iron cannon ball of mass 800 kg and density 8000 kg m^{-3} is attached to a lifting bag of negligible volume and mass. Both the cannon ball and the lifting bag are submerged in seawater. The density of the seawater is 1050 kg m^{-3}.

(i) Show that the upthrust acting on the cannon ball is 1030 N.

[1]

(ii) Estimate the initial acceleration of the cannon ball when 0.70 m^3 of air is suddenly released into the bag.

acceleration = ... $m\ s^{-2}$ [2]

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(c) An iceberg floating in seawater is extremely dangerous because much of the ice is below the surface. This hidden ice can damage a ship that is still a considerable distance from the visible ice. Determine the fraction of the iceberg that lies below the water level. Assume density of ice and seawater are 917 kg m^{-3} and 1050 kg m^{-3} respectively.

fraction = ... [2]

3 Two blocks A and B of masses 0.30 kg and 0.50 kg respectively, are connected by a string that passes over a pulley as shown in Fig. 3.1. The tabletop and pulley are frictionless and the string is inextensible. The system is released from rest. Block A moves along the tabletop and strikes a spring that is firmly attached to the tabletop. The spring has a spring constant of 360 N m^{-1}.

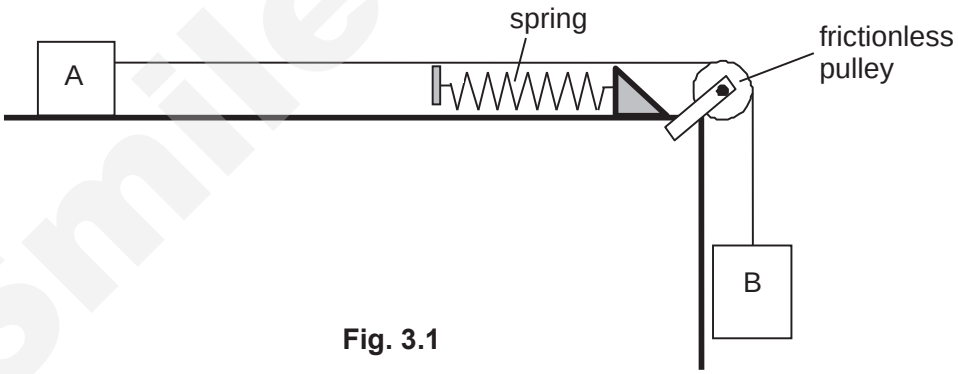

Fig. 3.1

(a) On Fig. 3.2, draw the free-body diagrams of blocks A and B after the system is released from rest. Label all forces clearly.



Fig. 3.2 [2]

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(b) **(i)** Show that the magnitude of the acceleration of block A is 6.13 m s^{-2} before striking the spring.

[2]

(ii) Hence determine the tension in the string before block A strikes the spring.

tension = …… N [1]

(c) Show that the acceleration of block A decreases linearly with its distance travelled immediately after it touches the spring.

[2]

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4 Fig. 4.1 shows a mass *m* attached to a spring performing *simple harmonic motion* in the vertical *y* direction. The spring constant *k* of the spring is 61.4 N m^{-1}.

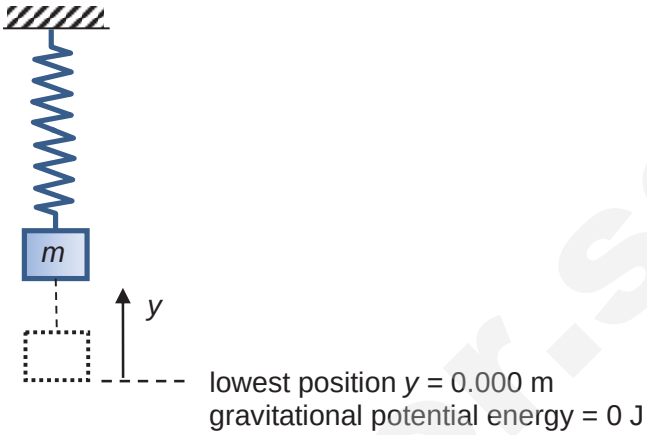

Fig. 4.1

At *y* = 0.000 m, the lowest point of the oscillation, the gravitational potential energy of the system is defined as 0 J.

As the system oscillates, its total energy is a *constant* composing of kinetic energy, elastic potential energy and gravitational potential energy. At different positions *y* above the lowest position of oscillation, the kinetic energy and the elastic potential energy of the system vary according to the graph in Fig. 4.2.

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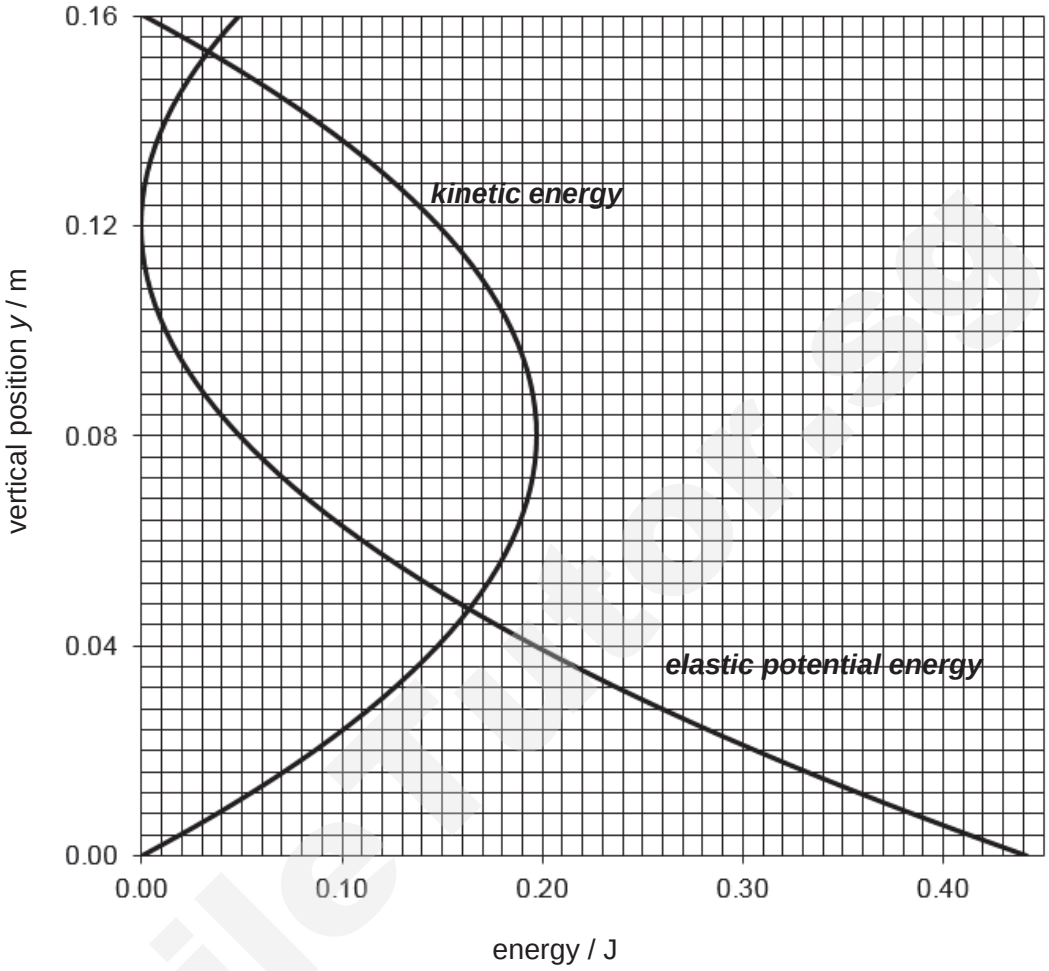

Fig. 4.2

Using the information presented in the graph, answer the following questions.

(a) Determine, with clear explanation, the *total energy* of the system.

total energy = ... J [2]

(b) Plot on Fig. 4.2 a line showing how the *gravitational potential energy* of the system would vary with *y*. [2]

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(c) Hence or otherwise, determine the mass m.

m = ... kg [2]

(d) Find the period T of the oscillation.

T = ... s [3]

(e) Evaluate the *work done by the spring force on m,* as m moves upwards from y = 0.000 m to y = 0.160 m.

work done = ... J [2]

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5 **(a)** Fig. 5.1 shows electric field lines around a metal needle which is held at a high positive voltage.

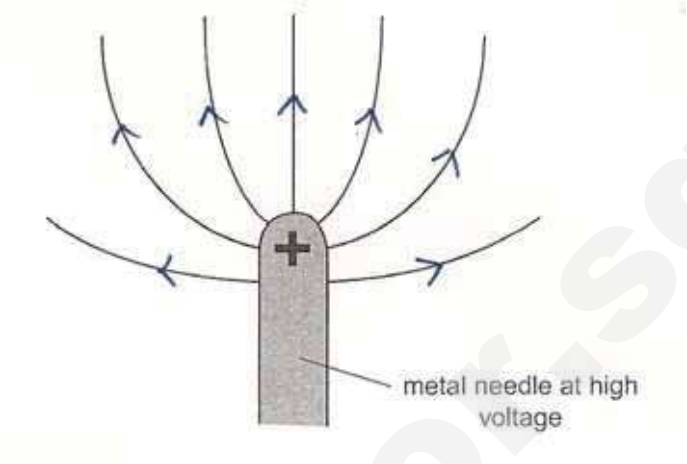

Fig. 5.1

(i) On Fig. 5.1, draw two equipotential lines around the charged metal needle. [1]

(ii) Suggest the effect of the electric field on the air molecules near the needle tip.

.....

.....

.....

..... [2]

(b) Fig. 5.2 shows a charged conducting sphere of diameter 4.00 mm which is connected to an insulating rod. The electric field strength at the surface of the conducting sphere is 1.13×10^7 V m^{-1}.

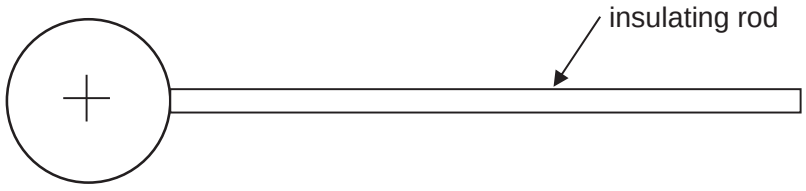

Fig. 5.2

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(i) Calculate

1. the magnitude of the charge on the conducting sphere.

magnitude of charge = ... C [2]

2. the electric potential of the charged sphere.

potential of charged sphere = ... V [1]

(ii) The charged sphere is placed on a top-pan balance as shown in Fig. 5.3. The reading on the balance is 8.205 g. The top-pan balance can record masses to the nearest 0.001 g.

An identical charged sphere is then clamped vertically above this sphere such that their centres are 4.0 cm apart.



Fig. 5.3

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1. Assuming that the spheres behave like point charges, determine the final reading on the balance.

final reading on balance = _____ g [3]

2. State and explain whether your answer to **(b)(ii)1.** is an under-estimate or an over-estimate if the assumption that the spheres behave like point charges is not valid.

_____

_____

_____

_____

_____ [2]

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6 **(a)** An oscilloscope is used to measure the potential difference across a 500 Ω resistor in an a.c. circuit. The voltage waveform is shown in Fig. 6.1.

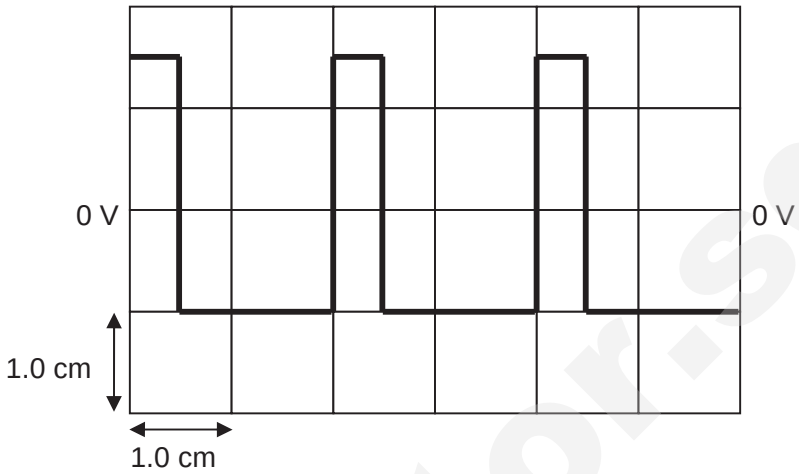

Fig. 6.1

Given that the time base of the oscilloscope is set at 5 ms cm^{-1} and its Y-gain is set at 0.5 V cm^{-1}, determine

(i) the frequency of the voltage waveform,

frequency = ... Hz [2]

(ii) the r.m.s. value of the potential difference across the resistor,

V_{rms} = ... V [2]

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(b) A large flat coil is connected in series with an ammeter and a 50 Hz sinusoidal alternating supply whose r.m.s. output can be varied. At the centre of this coil is situated a much smaller coil which is connected to the Y-plates of a cathode-ray oscilloscope. The planes of the two coils are coincident as shown in Fig. 6.2.

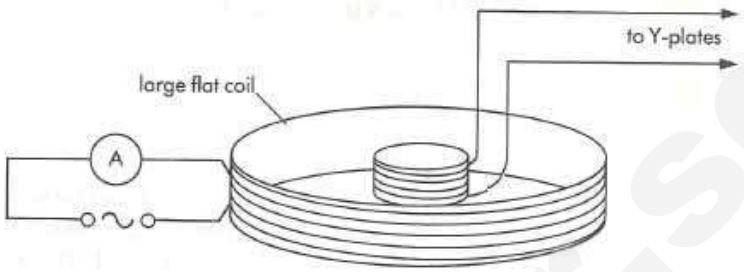

Fig. 6.2

(i) Using the axes in Fig. 6.3, sketch

1. a graph to show the variation with time of the magnetic flux, and

2. a graph to show the variation with time of the induced e.m.f., in the small coil.

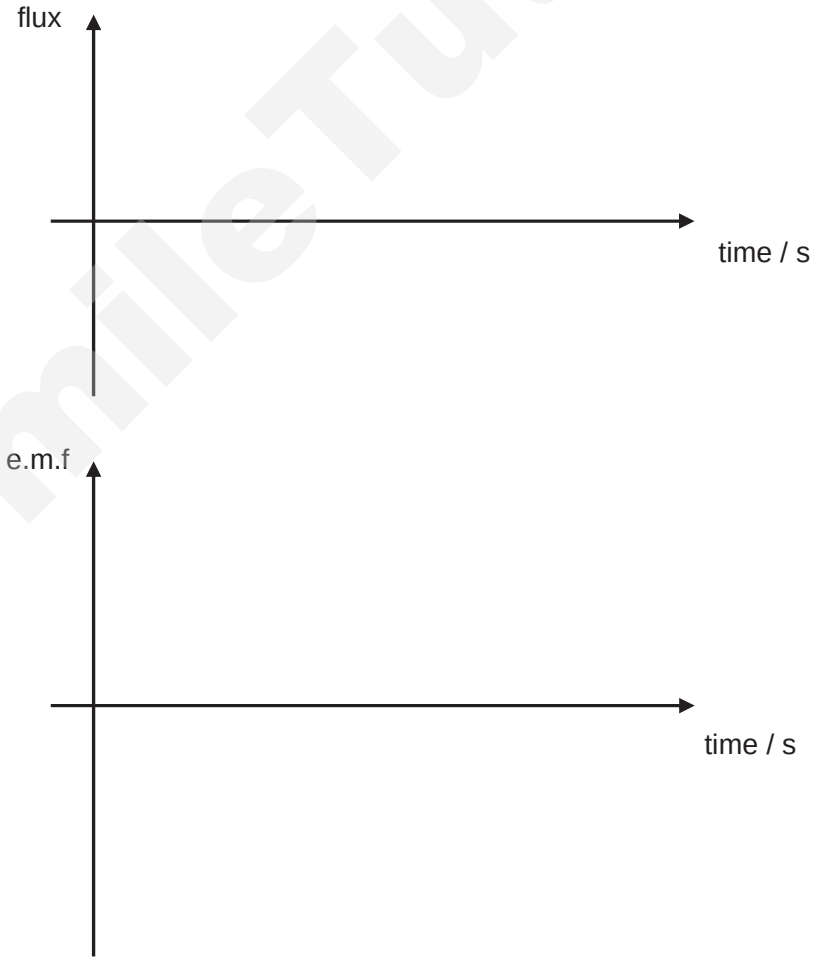

Fig. 6.3 [2]

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(ii) State the changes, if any, to part **(i)2.** when the frequency of the alternating current is doubled.

.....

..... [2]

(iii) State and explain how the trace on the screen of the cathode-ray oscilloscope would be affected if the angle between the planes of the two coils is slowly increased from 0° to 90° whilst maintaining a constant r.m.s. current in the large coil.

.....

..... [2]

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Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** **(i)** Explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle.

.....

.....

.....

..... [2]

(ii) Newton's law of gravitation applies to point masses.
Explain why, although the planets and the Sun are not point masses, the law also applies to planets orbiting the Sun.

.....

..... [1]

(b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.98×10^{24} kg concentrated at its centre, as illustrated in Fig. 7.1.

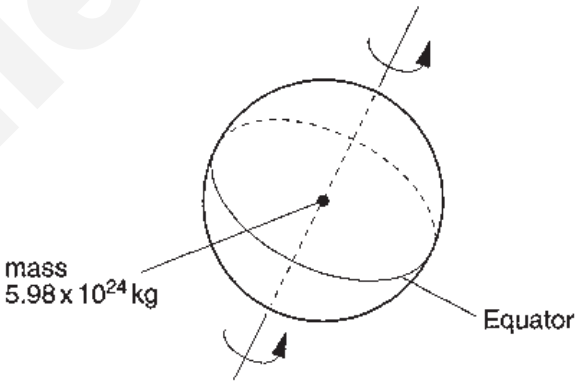

Fig. 7.1

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.00 day. Calculate, to three significant figures,

(i) the gravitational force F_G of attraction between the mass and the Earth,

F_G = ... N [2]

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(ii) the centripetal force F_C on the 1.00 kg mass.

F_C = ... N [2]

(iii) By reference to your answers in **b(i)** and **(b)(ii)**, determine the acceleration of free fall at the equator. Explain your answer.

.....

.....

.....

..... [2]

(c) Astronauts in space adopt a way to simulate gravity through the rotation of the spacecraft as shown in Fig. 7.2. A person, standing on the interior circumference of a spacecraft with radius r (in metres), experiences artificial gravity when the spacecraft rotates at a rate of f revolutions per minute.

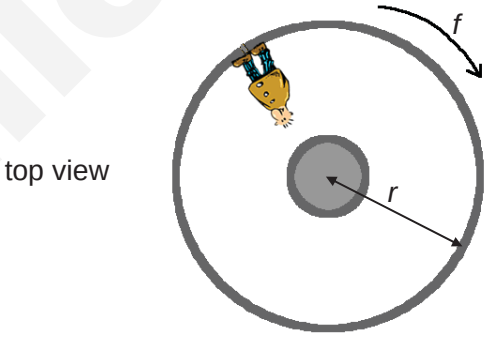

Fig. 7.2

(i) State the force that provides the centripetal force.

..... [1]

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(ii) Show that the artificial gravitational field strength k (in S.I. units) experienced by the person can be expressed as $k = 0.0110\, r\, f^2$.

[2]

(iii) Studies have shown that humans develop debilitating motion sickness when the rate of rotation exceeds 2.0 revolutions per minute. Determine the minimum radius of the spacecraft that will be able to create *artificial gravity* equivalent to the one found near the surface of the Earth at a rotation humans can tolerate.

r = ... m [2]

(d) Fig. 7.3 represents three equipotential surfaces associated with the gravitational field of Mars.

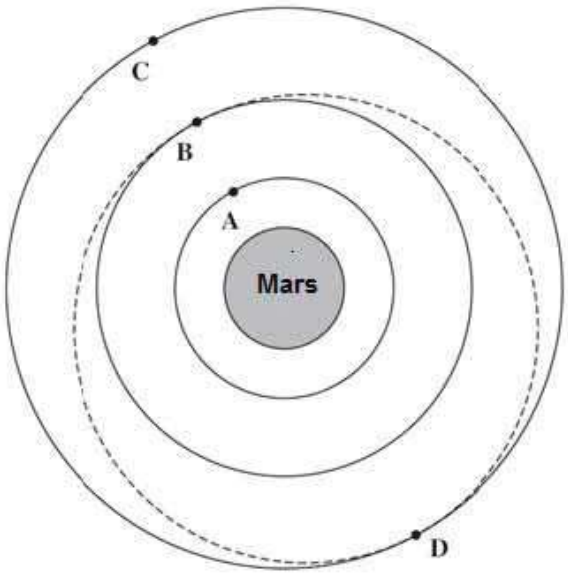

Fig. 7.3

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The points labelled A, B, C and D lie on the equipotential surfaces. The gravitational potential at the surface of Mars is -12.6 MJ kg^{-1}.

(i) State what is meant by the statement that '*the gravitational potential at the surface of Mars is -12.6 MJ kg^{-1}*'.

.....

.....

..... [2]

(ii) Fig. 7.4 shows the distances *r* of these equipotential surfaces from the centre of Mars and the gravitational potential *V* at each surface. Complete Fig. 7.4.

	r /km	*V* /MJ kg^{-1}
A	6800	
B	10200	
C	13600	- 3.16

Fig. 7.4 [2]

(iii) An unpowered satellite of mass 850 kg passes point D at a speed of 1.64 x 10^3 m s^{-1}. This satellite follows the elliptical orbit shown by the dotted line in Fig. 7.3. In this orbit, the radius of the orbit about the centre of Mars is continually changing. Using energy considerations, show that the speed of this satellite when it passes point B is approximately 2.2 x 10^3 m s^{-1}.

[2]

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8 A uranium ($^{238}_{92}$U) nucleus, originally at rest, spontaneously decays to form a thorium (Th) nucleus and an α-particle. A γ-ray is not emitted.

(a) Write down the nuclear equation which describes this disintegration.

.....[1]

(b) The α-particle emitted in this disintegration travelled 25 mm in a cloud chamber, ionising the fluid within. Given that, on average, an α-particle creates 5.0×10^3 ion pairs per mm of track in the cloud chamber and that the energy required to produce an ion pair is 5.2×10^{-18} J, show that the speed with which the α-particle was emitted is 1.4×10^7 m s^{-1}.

[2]

(c) **(i)** Deduce the speed of the thorium nucleus after the disintegration.

speed of thorium nucleus = ... m s^{-1} [2]

(ii) Describe the motion of the thorium nucleus relative to the α-particle.

.....

.....[1]

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(iii) Briefly describe how your answer to **(ii)** would differ if the uranium nucleus is originally moving in one direction and the α-particle is emitted in a perpendicular direction.

.....

..... [1]

(d) Calculate the difference between the rest mass of the original uranium nucleus and the sum of the rest masses of the products of the disintegration.

difference = ... kg [3]

(e) Uranium-238 has a half-life of 4.5×10^9 years.

(i) Define *half-life* and *decay constant* for a radioactive substance.

half-life .....

.....

decay constant .....

..... [2]

(ii) Calculate the decay constant for uranium-238.

decay constant = ... s^{-1} [2]

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(f) A certain coal-fired power station burns 80 megatonnes of coal a year. The coal contains a 0.0002% impurity of uranium-238 of which 10% is discharged into the atmosphere as fly ash during combustion.

(i) Assuming that, on average, the fly ash takes one year to fall to earth, show that the mass of uranium-238 in the air at any one time is 1.6×10^4 kg.

[1]

(ii) Hence calculate the number of α-particles produced per unit time from the uranium-238 in the air.

number per unit time = _____ s^{-1} [3]

(iii) Suggest a reason why fly ash poses a radiation hazard.

_____

_____

_____ [2]

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2017 TJC H2 Physics Prelim Paper 3 Solutions

Section A

1 (a) The internal energy of a gas is the sum of the kinetic energy of all the molecules due to their random motion and the potential energy of all the molecules due to their positions relative to each other and the forces between them. B1

(b) (i) $W_{grav} = m\,g\,x = (60.0)(9.81)(5.00 \times 10^{-2})$ A1
$= 29.4$ J

(ii) $W_{elastic} = \frac{1}{2}\,k\,x^2 = \frac{1}{2}\,(50.0 \times 10^{3})(5.00 \times 10^{-2})^2$ C1
$= 62.5$ J A1

(iii) $W_{atm} = (p_{atm}\,A)\,x = (1.00 \times 10^{5})(3.00 \times 10^{-2})(5.00 \times 10^{-2})$ C1
$= 150$ J A1

(iv) $W_{by} = W_{grav} + W_{elastic} + W_{atm} = 29.4 + 62.5 + 150 = 242$ J C1

$\Delta U = Q_{in} + W_{on} = 200 - 242$ C1
$= -42$ J A1

(v) $F_{gas\ on\ piston} = mg + kx + F_{atm\ on\ piston}$ C1

$p_{gas}A = mg + kx + p_{atm}A$ C1

$$p_{gas} = \frac{(mg + kx)}{A} + p_{atm}$$
$$= \frac{(60.0)(9.81) + (50.0 \times 10^{3})(5.00 \times 10^{-2})}{(3.00 \times 10^{-2})} + (1.00 \times 10^{5})$$
$= 2.03 \times 10^{5}$ Pa A1

2 (a) (i) Upward force acting (on body) by fluid due to fluid displaced A1

(ii) Due to pressure difference between the top and bottom of the body. Pressure in fluid increases with depth. A1

(iii) Upthrust = ρVg. Thus conditions are:
1. incompressible fluid – fluid of constant density ρ B1
2. incompressible/rigid body – body of constant volume V B1

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(b) **(i)** $U = \rho_w Vg = \rho_w \left(\frac{m}{\rho}\right) g$

$= 1050\left(\frac{800}{8000}\right) 9.81 = 1030 \text{ N (shown)}$ B1

(ii) *Let U' = new upthrust due to water displaced by air* C1

$\uparrow +$ $U' + 1030 - mg = ma$

$\Rightarrow 1050\ (0.70)\ 9.81 + 1030 - 800\ (9.81) = 800a$

$\Rightarrow a = 0.49 \text{ m s}^{-2}$ A1

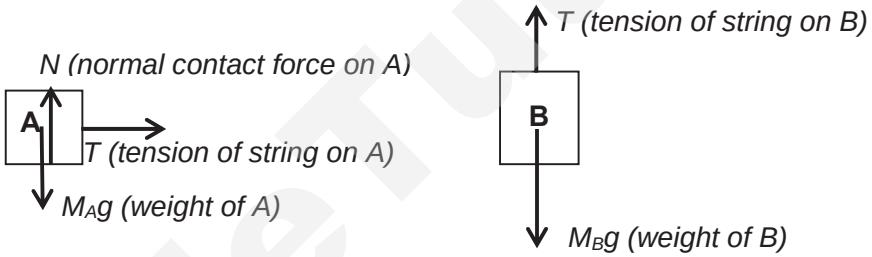
(c) *By Principle of Flotation*

$U = mg$ C1

$\rho_w V_w g = \rho_i V_i g$ where V_w = volume of water displaced

Required fraction = $\frac{V_w}{V_i} = \frac{\rho_i}{\rho_w} = \frac{917}{1050} = 0.87$ A1

3 **(a)**



A2

(b) **(i)** *Block A:* $T = M_A a$ —— (1)

Block B: $M_B g - T = M_B a$ —— (2) *M1*

(1) + (2): $M_B g = (M_A + M_B) a$

$0.50\ (9.81) = (0.30 + 0.50) a$ *M1*

$\Rightarrow a = 6.13 \text{ m s}^{-2}$

(ii) *From (1):* $T = M_A a = 0.30\ (6.13) = 1.84$ N *B1*

(c) *Block A:* $T - kx = M_A a$ —— (1)

Block B: $M_B g - T = M_B a$ —— (2)

(1) + (2): $M_B g - kx = (M_A + M_B)\ a$ *M1*

$$\Rightarrow a = \frac{M_B g}{M_A + M_B} - \frac{kx}{M_A + M_B}$$

$$= \frac{0.50(9.81)}{0.80} - \frac{360x}{0.80} = 6.13 - 450x$$ *M1*

The equation is of the form $a = A - Bx$ where A and B are constants.
Thus block A decreases linearly with its distance travelled immediately after it touches the spring.

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4 **(a)** At y = 0.000 m,
$TE = KE + GPE + EPE$ C1
$= 0 + 0 + 0.442$
$= 0.442$ J A1

-Accept answer between 0.440 J and 0.445 J.

(b) Straight line B1
passing through the origin and (0.393, 0.160). B1

-1. At y = 0.160 m, $TE = KE + GPE + EPE$
$0.442 = 0 + GPE + 0.049 \Rightarrow GPE = 0.393$ J
Acceptable value for the GPE at y = 0.160 m ranges from 0.390 J to 0.395 J.
2. Students who draw curves get zero mark.

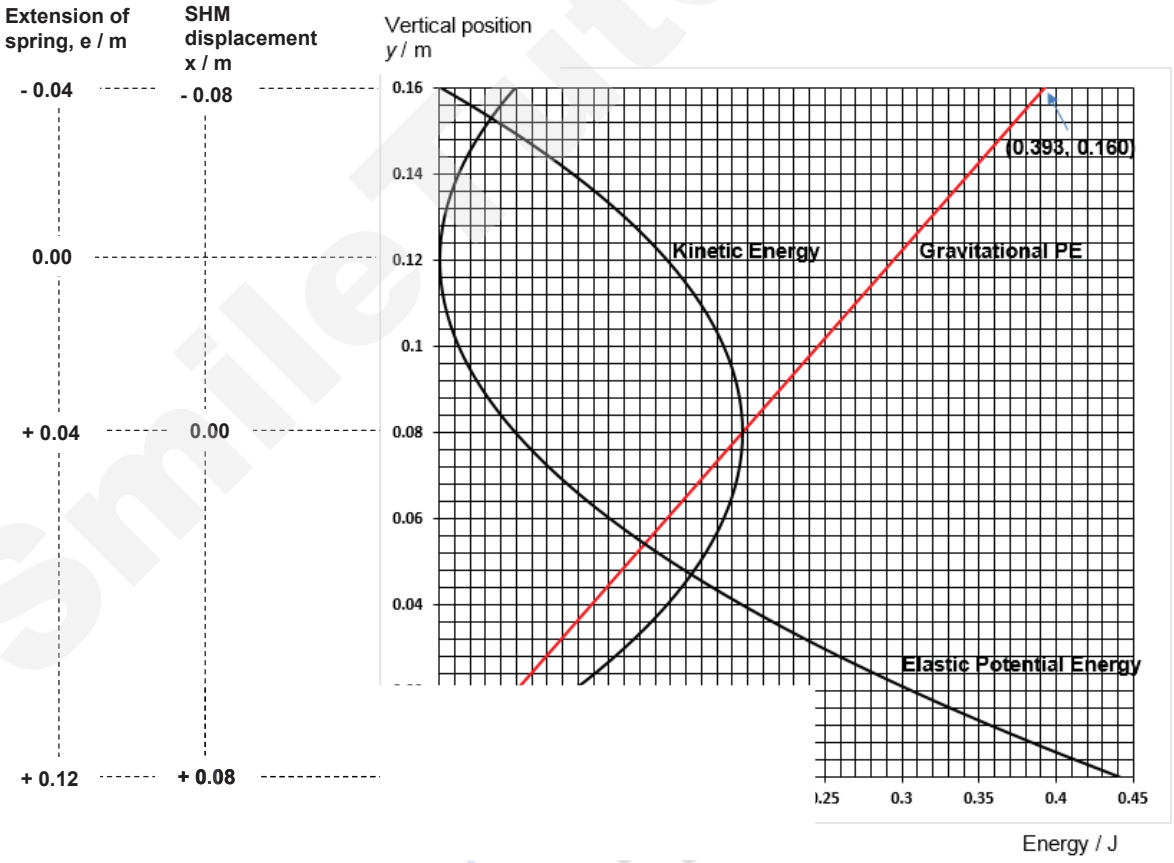

Fig. 4.1

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(c) Method 1:
Consider (0.393, 0.160) on *GPE* line, C1
mg (0.160) = 0.393
m = 0.250 kg A1

Method 2:
At y = 0.080 m, the equilibrium position of the SHM, extension e of spring is 0.040 m. (See Fig. 4.1). There is no net force on m, thus
$ke = mg$
$(61.4)(0.040) = m\,(9.81) \Rightarrow m = 0.250$ kg

(d) Method 1:

$$KE_{max} = \frac{1}{2}mv_o^{\,2} = \frac{1}{2}m\omega^2 x_o^{\,2} \quad \Rightarrow \quad 0.196 = \frac{1}{2}(0.250)(\frac{2\pi}{T})^2(0.080)^2$$ C2

T = 0.401 s A1

Method 2:

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.25}{61.4}} = 0.401\,\text{s}$$

Method 3:
At y = 0.000 m, the extension of spring is maximum, e_{max} = 0.120 m. The mass is at its amplitude position in its SHM, so displacement is x_o = 0.080 m. (See Fig. 4.1).

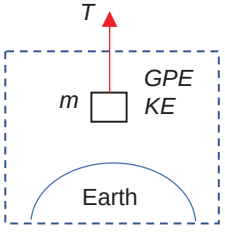
↑+: $F_{net} = ma \quad \Rightarrow \quad ke_{max} - mg = ma_o$

$$ke_{max} - mg = m(\omega^2 x_o)$$
$$(61.4)(0.12) - (0.25)(9.81) = (0.25)(\omega^2\,(0.08))$$
$$T = \frac{2\pi}{\omega} = 0.401\,\text{s}$$

(e) Method 1:
EPE is related to the spring force T via the equation $T = -\frac{\mathrm{d}(EPE)}{\mathrm{d}e}$, where e is the C1
extension of the spring. So work done by T is

$$W_T = \int T.\,\mathrm{d}e = -\int \mathrm{d}(EPE) = -\Delta EPE$$
$$= -(EPE_{final} - EPE_{initial})$$
$$= -(0.049 - 0.442) \quad \text{, read from}$$

EPE graph or cal. from ½ke^2 A1
= + 0.393 J



Method 2: System of mass and earth
$W_T = \Delta KE + \Delta GPE$
= 0 + [mg(0.16) – 0]
= 0.25(9.81)(0.16)
= + 0.392 J
Nb: gain in *GPE* is positive over distance moved.

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Method 3: System of mass only

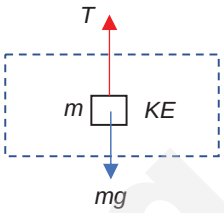
$W_{net} = \Delta KE$

$W_T + W_{grav} = 0$

$W_T = -W_{grav}$

$= -[-mg(0.16)] = +0.392$ J

Nb: work done by gravitational force is negative over distance moved.



5 (a) (i) *B1*



-the equipotential lines and the field lines must intersect at right angles. When these lines are slightly off, benefit of doubt is given for candidates who indicated the requirement with right angle signs.

(ii) Strong electric field near the sharp tip removes electrons from/ionises air molecules. *M1*

Electrons and positive ions move off in opposite direction giving rise to an electric current. (Electrical breakdown of air occurs.) *A1*

(b) (i)1. $E = \dfrac{Q}{4\pi\varepsilon_o r^2}$

$1.13 \times 10^7 = \dfrac{Q}{4\pi \times 8.85 \times 10^{-12} \times (2.00 \times 10^{-3})^2}$ C1

$Q = 5.03 \times 10^{-9}$ C A1

2. $V = \dfrac{1}{4\pi\varepsilon_o}\dfrac{Q}{r} = E \times r = 1.13 \times 10^7 \times 2.00 \times 10^{-3}$

$= 2.26 \times 10^4$ V A1

(ii)1. $F = \dfrac{1}{4\pi\varepsilon_o}\dfrac{Q_1 Q_2}{r^2}$

$= \dfrac{1}{4\pi \times 8.85 \times 10^{-12}} \dfrac{(5.03 \times 10^{-9})^2}{(4.0 \times 10^{-2})^2}$

$= 1.42 \times 10^{-4}$ N C1

This electric force of repulsion results in greater contact force exerted by the lower sphere on the top-pan balance.

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$m'g = N' = mg + F$

$\Rightarrow m' = m + \frac{F}{g} = 8.205 + \frac{1.42 \times 10^{-4}}{9.81} \times 1000$ C1

$= 8.219$ g (3 d.p. since balance can read masses to 0.001 g) A1

2. Due to repulsion, charges accumulate on the outer sides of the two spheres. Thus the effective distance between the charges (on both spheres) increases. The electrostatic force will be smaller. M1
The actual reading m' will be smaller. Thus answer in **(b)(ii)1**. is an over-estimate. A1

6 **(a)(i)** Period = 2 cm × 5 ms cm^{-1} = 10 ms C1

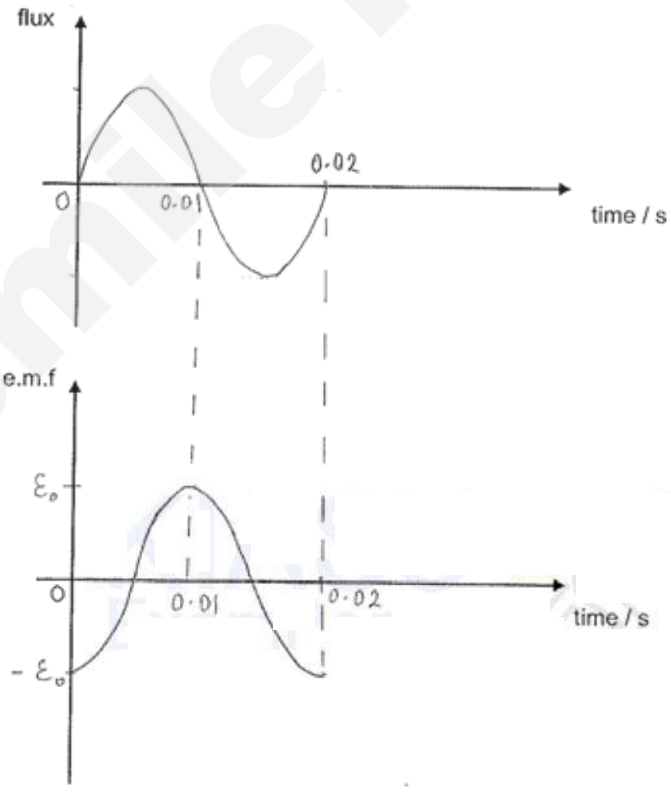
$\Rightarrow$ frequency

$= \frac{1}{T} = \frac{1}{10 \times 10^{-3}} = 100$ Hz A1

(ii) $V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{\frac{0.75^2 \times 2.5 + 0.5^2 \times 7.5}{10}}$ C1

$= 0.573$ V A1

(b)(i)



A1

A1

1 mark deducted if period is not indicated along t-axis.

(ii) Amplitude/peak/ maximum e.m.f. is doubled B1

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frequency is doubled (or period is halved) B1

(iii) The ***magnetic flux (produced by the large coil) linking the small coil*** will decrease to zero. M1

Thus, the amplitude of the trace (which is the induced e.m.f. in the small coil) will decrease to zero. A1

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Section B

7 **(a)(i)** A body moving with uniform speed in a circle experiences a continuous change in velocity due to a continuous change in direction. Hence it experiences an acceleration. *B1*

The acceleration and hence the net force must act towards the centre of the circle because the change in velocity acts towards the centre / there cannot be a component of acceleration tangential to the circle for constant speed / the acceleration must be perpendicular to the motion so that no work is done on the body moving at uniform speed. *B1*

(a)(ii) Planets and Sun are like spheres of uniform density. Each behaves like a point mass as the gravitational field strength at a distance outside is the same as that due to a point mass at the centre of the sphere / the gravitational field lines point radially inward towards its centre / all the mass of each sphere seems to act from its centre. *B1*

(b)(i) $F_G = \dfrac{GMm}{R^2} = \dfrac{6.67\times10^{-11}(5.98\times10^{24})(1.00)}{(6380\times10^{3})^2}$ C1

$= 9.80\ \text{N}$ A1

(b)(ii) $F_C = mR\omega^2 = mR\left(\dfrac{2\pi}{T}\right)^2$ C1

$= (1.00)(6380\times10^{3})\left(\dfrac{2\pi}{24\times60\times60}\right)^2$

$= 0.0337\ \text{N}$ A1

(b)(iii) Part of gravitational force provides the centripetal force. Acceleration (of free fall) is force per unit mass. B1

$\therefore$ acceleration = 9.77 m s^{-2} A1

(c)(i) Normal contact force acting on the man by the spacecraft. A1

(c)(ii) $a = r\omega^2$

$= r(2\pi f')^2$ *where f' is revolutions per s* M1

$= r\left(2\pi\dfrac{f}{60}\right)^2$ *where f is revolutions per* min*ute* M1

$= 0.0110\, rf^2$ A0

(c)(iii) $k = 0.0110$ *r f* ^{2}

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$9.81 = 0.0110 r_{min} (2.0)^2$ M1

$r_{min} = 224$ m A1

(d)(i) -12.6 MJ of work is done by external agent to move a mass of 1 kg from infinity to that point. B2

(d)(ii) Use $\phi = -\frac{GM}{r} \alpha \frac{1}{r}$

	r /km	*V* /MJ kg^{-1}
A	6800	**-6.32**
B	10200	**- 4.21**
C	13600	- 3.16

A1

A1

(d)(iii) By COE :

$KE_B + PE_B = KE_D + PE_D$

$\frac{1}{2} m v_B^{\ 2} + m(-4.21 \times 10^6) = \frac{1}{2} m (1.64 \times 10^3)^2 + m(-3.16 \times 10^6)$ C2

$v_B = 2.2 \times 10^3$ m s^{-1} A0

8 **(a)** $^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$ A1

(b) Energy of the emitted α-particle = $(5.0 \times 10^3) \times 25 \times (5.2 \times 10^{-18}) = 6.5 \times 10^{-13}$ J C1

$\frac{1}{2} mv^2 = 6.5 \times 10^{-13}$

$\frac{1}{2} \times 4 \times 1.67 \times 10^{-27} v^2 = 6.5 \times 10^{-13}$ C1

$\therefore v = 1.4 \times 10^7$ m s^{-1} A0

(c) **(i)** By conservation of momentum,

$m_{Th} v_{Th} = m_\alpha v_\alpha$

$v_{Th} = \frac{4}{234} \times 1.4 \times 10^7$ C1

$= 2.4 \times 10^5$ m s^{-1} A1

(ii) The thorium nucleus travels in the opposite direction relative to the α-

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particle. A1

(iii) The thorium nucleus and the α-particle no longer travel in opposite directions/ move off in a fork. (total momentum is conserved.) B1

(d) K.E. of thorium nucleus = ½ × 234 × 1.67 × 10^{-27} × (2.4 × 10^{5})^2 = 1.125 × 10^{-14} J M1

$E = \triangle m\, c^2$

1.125 × 10^{-14} + 6.5 × 10^{-13} = $\triangle m$ × (3.00 × 10^{8})^2 M1

$\triangle m$ = 7.3 × 10^{-30} kg A1

(e) **(i)** Half-life is the average time taken for half of the number of radioactive nuclei to decay. B1

Decay constant is the probability per unit time that a radioactive nucleus will decay. B1

(ii) $\lambda = \ln 2 / t_{1/2}$

$= \dfrac{\ln 2}{4.5\times10^{9}\times365\times24\times3600}$ C1

= 4.9 × 10^{-18} s^{-1} A1

(f) **(i)** Mass of uranium-238 = 0.000002 × 80 × 10^{9} × 0.1 = 1.6 × 10^{4} kg B1

(ii) number of α-particles produced per unit time = $A = \lambda N$

$= \lambda \times \dfrac{M}{M_m} N_A$ C1

= 4.9 × 10^{-18} × $\dfrac{1.6\times10^{4}}{238\times10^{-3}}$ × 6.02 × 10^{23} C1

= 2.0 × 10^{11} s^{-1} A1

(iii) When fly ash settles on landfills, mines or quarries, B1

people living next to these areas are exposed to higher levels of radiation from uranium. B1

OR

When fly ash dissolves in water/seeps into soil, B1

uranium contaminates rivers/streams/lakes/vegetation, making drinking water unsafe/ affecting crops and making food unsafe for consumption. B1

OR

When fly ash is inhaled, B1

uranium accumulates in the lungs causing destruction of DNA/mutation of cells leading to cancer. B1

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TEMASEK JUNIOR COLLEGE
2017 JC2 PRELIMINARY EXAMINATION
Higher 2

NAME

CG

PHYSICS 9749/04

PAPER 4

24 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and C.G. in the spaces provided at the top of this page.
Write in dark blue or black pen on both sides of the papers.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.
Answer **all** questions.

Write your answers in the spaces provided in this booklet.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
TOTAL	

This booklet consists of 16 printed pages.

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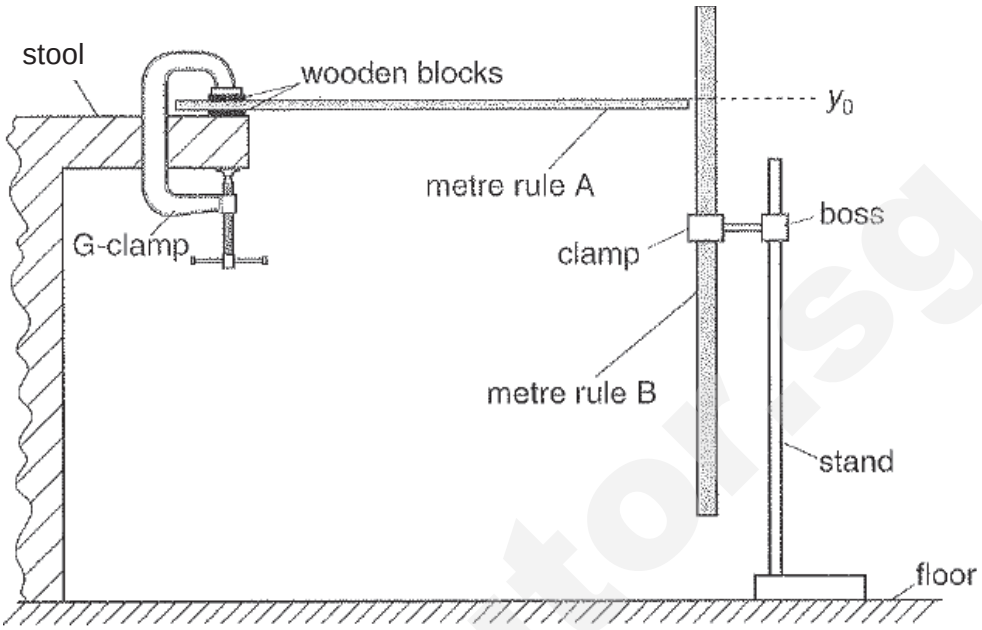
1 In this experiment, you will investigate the deflection of a loaded metre rule.

(a) **(i)** Set up the apparatus as shown in Fig. 1.1



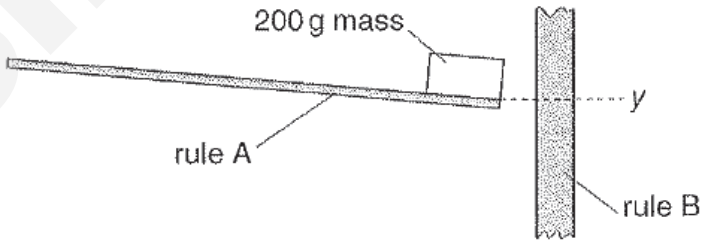
y_o is the point on rule B level with the top of rule A.

Fig. 1.1

(ii) Record the reading y_o.

y_o = ...

(iii) Place a 200 g mass on the end of rule A as shown in Fig 1.2.



y is the point on rule B level with the top of rule A.

Fig. 1.2

(iv) Record the reading y.

y = ...

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(v) Remove the 200 g mass from rule A.

(vi) Calculate the deflection ($y - y_o$).

$(y - y_o)$ = ...

(vii) Determine the percentage uncertainty in ($y - y_o$).

percentage uncertainty in $(y - y_o)$ = ...

(b) **(i)** Repeat **(a)(ii).**

y_o = ...

(ii) Place the 200 g mass at a position approximately half way along the overhanging length of rule A.

(iii) Repeat **(a)(iv)**, **(a)(v)** and **(a)(vi)** with the 200 g mass placed at this new position.

y = ...

$(y - y_o)$ = ...

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(c) **(i)** It is suggested that:

"If both masses are placed on rule A in different positions at the same time, the deflection will equal the sum of the deflections for each mass on its own."

Take more readings to investigate this suggestion. Present your results in a table.

(ii) State whether or not the results of your experiment support this suggestion.

Justify your answer by referring to your calculated percentage uncertainty in **(a)(vii)**.

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(d) **(i)** State a significant source of error in this experiment.

.....

.....

.....

(ii) Suggest one improvement that could be made to the experiment to address the source of error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

.....

.....

.....

[Total : 9 marks]

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2 In this experiment you will investigate the effect of a movable mass on the behaviour of a compound pendulum.

(a) (i) Set up the apparatus as shown in Fig. 2.1. The nail should be passed through the ring at the end of the long metal rod and clamped to the retort stand. The rod should swing easily from the nail and should be well clear of the bench.

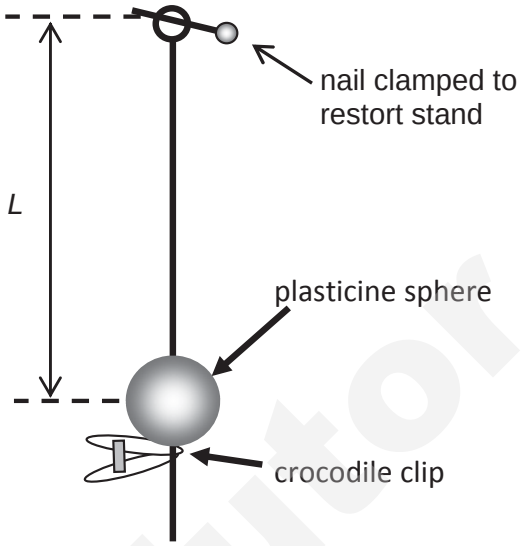

Fig. 2.1

The distance *L* is between the pivot to the centre of the plasticine sphere.

(ii) Set *L* to approximately 55 cm.

Measure and record the length *L*.

L = ... [ ]

(iii) Estimate the percentage uncertainty in your value of *L*.

percentage uncertainty in *L* = ... [ ]

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(iv) Explain how you measured the distance *L* as accurately as possible.

(b) **(i)** Displace the plasticine to one side. Release and allow it to oscillate.

Determine the period *T* of these oscillations.

T = ---

(ii) Calculate T^2.

T^2= ---

(c) Repeat **a(ii)**, **b(i)** and **b(ii)** using different length *L*. The distance *L* should be between 30 cm to 55 cm.

Present your results in a table.

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(d) (i) Plot a graph on Fig 2.2 using your values from **(c)**.

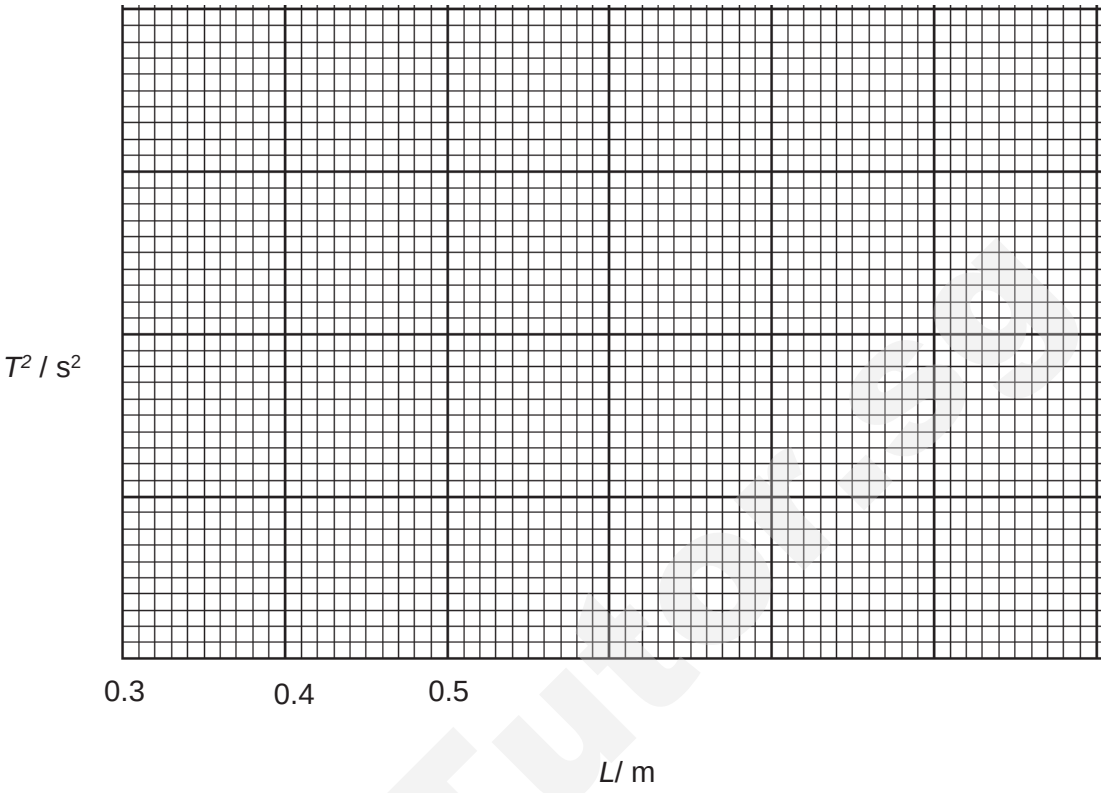

Fig 2.2

(d) (ii) State the relationship between T^2 and L based on your graph.

(iii) Theory suggests that the acceleration of free fall g is given by

$$g = \frac{4\pi^2 L_o}{T_o^2}$$

where T_o is the period of oscillation of the rod without the plasticine and L_o is the equivalent L value that will give T_o.

Describe the measurement that could be made and explain how you will calculate g using the graph obtained in **d(i).**

[Total: 14 marks]

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3 In this experiment, you will investigate constantan wire.

(a) **(i)** You have been provided with two lengths of constantan wire attached to mountings labelled M and N, an unknown resistor Y, and six resistors labelled with their resistance values in ohms.

Connect the circuit as shown in Fig. 3.1

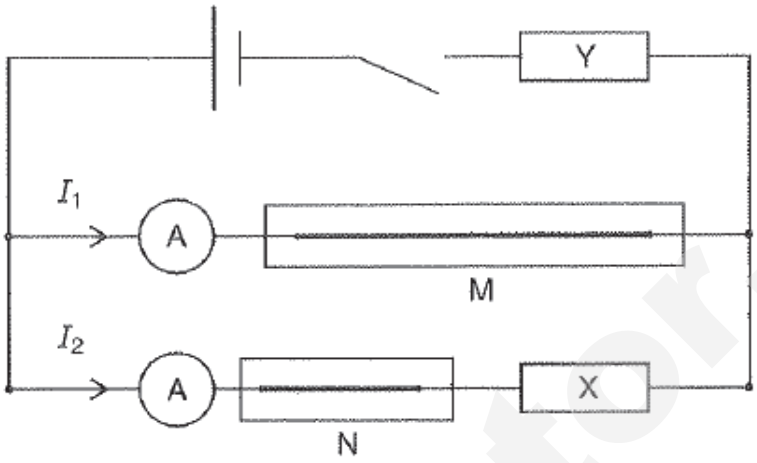

Fig. 3.1

The resistor X should be one of the resistors provided which has its value attached.

(ii) Record *R*, the resistance of X.

R = ...

(iii) When the switch is closed, the current through M is I_1 and the current through N is I_2.

Close the switch and record I_1 and I_2.

.

I_1 = ...

I_2 = ...

(iv) Open the switch.

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(b) Change X and repeat **(a)(ii)**, **a(iii)** and **a(iv)** for further values of R.

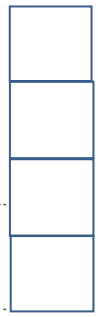


(c) I_1 and I_2 and R are related by the expression

$$\frac{I_1}{I_2} = PR + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.



P = ...

Q = ...

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Graph paper

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(d) Standard wire guage (swg) describes the diameter of a wire.

The data in the table shows the diameter *d* and resistance per metre *R*' for constantan wire of different swg.

swg	d/ mm	R'/ Ωm^{-1}
26	0.46	3.0
28	0.38	4.4
30	0.32	6.3
32	0.27	8.3
34	0.23	11.4
36	0.19	16.8
38	0.15	27.0
40	0.12	43.3

Theory suggests that the resistance of wire M = $\frac{1}{P}$.

Use the value from **(c)** and the data in the table to identify the wire used in this experiment.

Explain your reasoning.

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(e) Theory suggests that $Q = \frac{\text{length of wire N}}{\text{length of wire M}}$

Explain whether your results support the theory.

.....

.....

.....

.....

.....

.....

(f) **(i)** The experiment is repeated with the length of wire M increased but the swg of the wire used for M and N kept the same.

On the graph grid on page 11, sketch a second graph to represent the new results. Label it Z.

(ii) State a problem that might arise if both wires M and N are shortened and constantan wire of swg 26 is used.

.....

.....

.....

.....

[Total: 20 marks]

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4 Flat circular coils carrying a current can be used in television sets to deflect a beam of electrons.

Fig. 4.1 illustrates the magnetic flux pattern due to a narrow circular coil carrying a current.

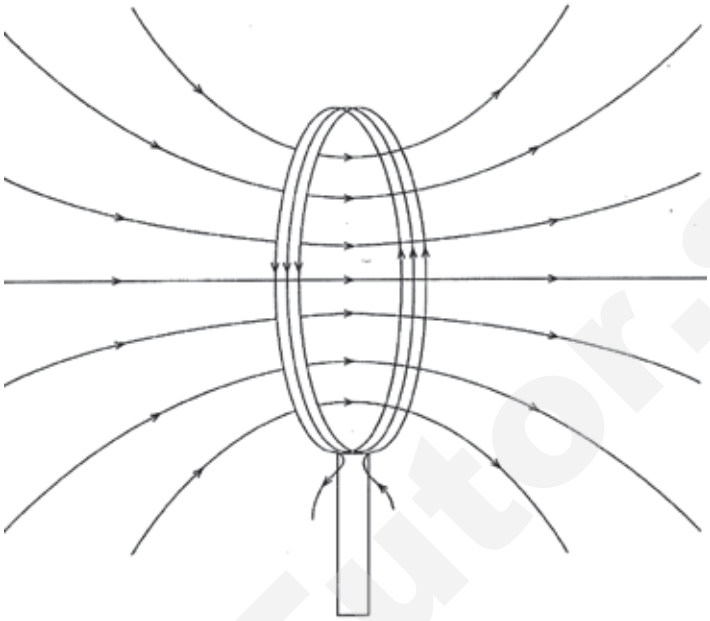

Fig 4.1

Theory suggests that the magnetic flux density *B* at the centre of a flat circular coil of *N* turns and radius *r* carrying a current I is given by the expression

$$B = \frac{\mu_0 NI}{2r}$$

where μ_0 is the permeability of free space.

Design an experiment to show that the magnetic flux density at the centre of a flat coil is directly proportional to the number of turns in the coil.

You should draw a diagram showing how the apparatus would be arranged. In your account, you should pay particular attention to

(a) the equipment you would use,

(b) the procedure to be followed,

(c) the method of measuring the magnetic flux density,

(d) the control of variables,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Diagram

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[Total : 12 marks]

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Name:_____ CG:_____ Date:_____

Suggested Mark Scheme for Q1:

Question	Marking Instructions	Mark	Score
1a(ii)	Values of y *and* y_o recorded to the nearest 0.5 mm or 1 mm with unit	1	
1a(vi)	Value of $y - y_o$ recorded to the nearest 1 mm with unit	1	
1a(vii)	Percentage uncertainty in $y - y_o$ calculated correctly using sensible value of $\Delta(y - y_o)$ ($\geq$1 mm)	1	
1b(iii)	Value of $y - y_o$ recorded to the nearest 1 mm with unit	1	
1c(i)	Take further 1 to 2 set of readings to appropriate precision Calculation of $\Delta y_1 + \Delta y_2$	1 1	
1c(ii)	Draw conclusion based on percentage uncertainty calculated in (a)(vii).	1	
2d(i)	Significant source of error	1	
2d(ii)	Improvement to address the errors identified	1	
	Total	9	

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Name:_____ CG:_____ Date:_____

Suggested Mark Scheme for Q2:

Question	Marking Instructions	Mark	Score
2a(ii)	*L* recorded to correct dp with units	1	
2a(iii)	Percentage uncertainty in *L* calculated correctly to appropriate sf (with $L \geq 2$ mm)	1	
2a(iv)	Measure the diameter of the plasticine sphere using the ruler. Measure the distance from the pivot to the top of the sphere and add the radius of the plasticine sphere (OR average of *L* for pivot to top/ *L* from pivot to bottom)	1 1	
2b(i)	Repeated timing for *t*, $t > 10$s Correct recording of t, *T* to correct dp/sf with unit	1 1	
2b(ii)	Correct calculation of T^2 to correct sf with unit	1	
2c	Take further 5 readings showing correct trend	1	
	Consistency in no. of dp/sf for raw readings/calculated values with correct unit	1	
2d(i)	All observations must be plotted. Work to an accuracy of half a small square. Plotted points occupy at least half the graph grid in both x and y directions. Best fit line- judge by scatter of points about the line drawn. There must be a fair scatter of points either side of the line.	1 1	
2d(ii)	-linearly related OR acceptable conclusion based on student's graph	1	
2d(iii)	-Perform oscillations of rod without plasticine to obtain T_0 -Calculate T_o^2 and obtain L_o from the graph and substitute into given equation to find *g*	1 1	
	Total	14	

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Name:_____ CG:_____ Date:_____

Suggested Mark Scheme for Q3:

No	Marking Instructions	Mark	Score
1	Correct recording of I_1 *and* I_2 to correct dp with correct unit	1	
2	Collected 6 or more sets of data (*R,* I_1 *and* I_2). Award 1 mark if assistance was rendered, or collected only 5 sets of data	2	
3	Each column heading must contain an appropriate quantity and unit	1	
4	Consistency in no. of dp for raw readings (*R* to nearest ohm, I_1 *and* I_2 to 1 dp,)	1	
5	Correct calculation of quantities ($\frac{I_1}{I_2}$) and all calculated values given to appropriate no. of sf/dp	1	
6	Linearising equation and deriving gradient/y-intercept of graph	1	
7	Appropriate scales – awkward scales (e.g. 3:10) are not allowed and scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Correct labelling of axes with correct units	1	
8	All observations plotted to an accuracy of half a small square	1	
9	Line of best fit – with a fair scatter of points on either side of the line	1	
10	Gradient – hypotenuse of the triangle is greater than half the length of the drawn line. Read-offs must be accurate to half a small square	1	
11	Y intercept – read off directly from the graph to half a small square or determined from $y = mx + c$ using a point on the line	1	
12	Value of *P and Q* calculated correctly with correct units, if any	1	
13	Correct calculation of resistance of M Correct calculation of resistance of R' Correct choice of swg of wire based on closeness of R' to given swg	1 1 1	
14	Correct calculation of Q based on equation given Appropriate justifications (e.g using percentage uncertainty)	1 1	
15	Straight line with smaller gradient and smaller Y-intercept	1	
16	Resistance decreases and hence current maybe too large and heat up wire	1	
	Total	20	

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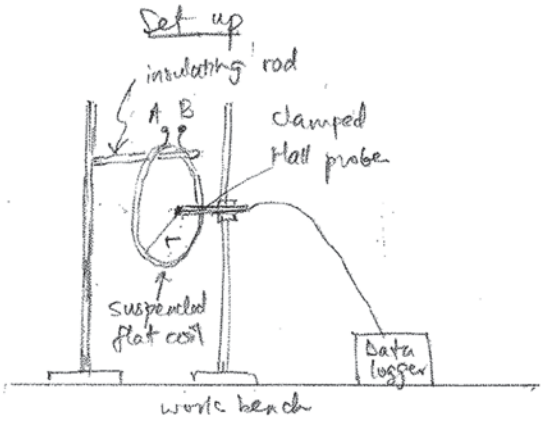
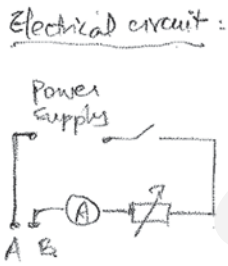
Name:_____ CG:_____ Date:_____

ELECTROMAGNETISM-FLAT CIRCULAR COIL





		Design
	A1	Diagram with workable arrangement: a flat coil connected to power supply
	A2	Hall probe placed at centre of coil and connected to data logger
	A3	Correct circuit diagram with power supply, ammeter and variable resistor
		Procedure
	B1	Method to prepare coils: 6 samples of coils of same radius, materials but different number of turns
	B2	Method of measuring magnetic field *B*: Hall probe connected to data logger/oscilloscope; OR search coil connected to ballistic galvanometer (if DC source) or to oscilloscope (if AC source); OR current balance with a very short wire within the coil
	B3	Repeat experiment for coils of different turns to obtain at least 6 sets of data
	B4	Ensure constant radius for different coils by coiling round a cylinder/measure diameter of each set of coil with ruler. Maintain constant current through the different coils as the number of turns is changed by adjusting the variable resistor
		Safety and analysis
	C1	Switch off the circuits when not in use to prevent overheating Wear gloves when handling hot coil
	C2	$B = \frac{\mu_o NI}{2r}$. Plot a graph of *B* versus *N*. If line is linear and through the origin, *B* is proportional to *N*
		Detail (Maximum 3 D marks)
	D1	Hall probe is right angles to the direction of magnetic field or give maximum output for each reading
	D2	Conduct the experiment away from other magnetic materials
	D3	Measure diameter in two perpendicular directions in the plane of the coil to determine centre of coil
	D4	Conduct a pre-experiment to determine a suitable current *I* OR suitable number of turns *N* for measurable *B*
	D5	A statement that Earth's magnetic field was negligible
	D6	Other possible good physics suggestions
	12	

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VICTORIA JUNIOR COLLEGE

2017 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **Higher 2**	**9749/01**
	21 Sep 2017
Paper 1 Multiple Choice	**THURSDAY**
	2 pm- 3 pm
Additional Materials: Multiple Choice Answer Sheet	**1 Hour**

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT group and shade your index number on the Answer Sheet provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers A B C and D**.**
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion,	$s = ut + (½)\,at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin\,\omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin\,\omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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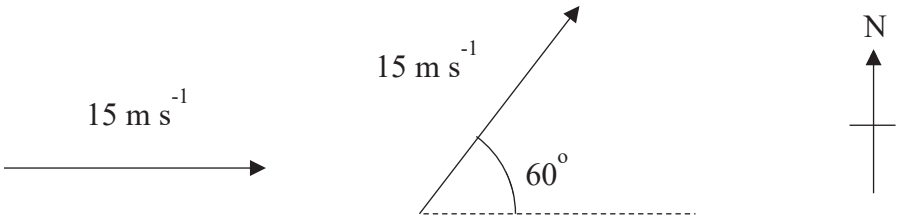
1 A car is initially travelling with a velocity of 15 m s^{-1} eastwards. At a later time, its velocity is 15 m s^{-1}, 60° north of east. The change of velocity of the car is



A zero

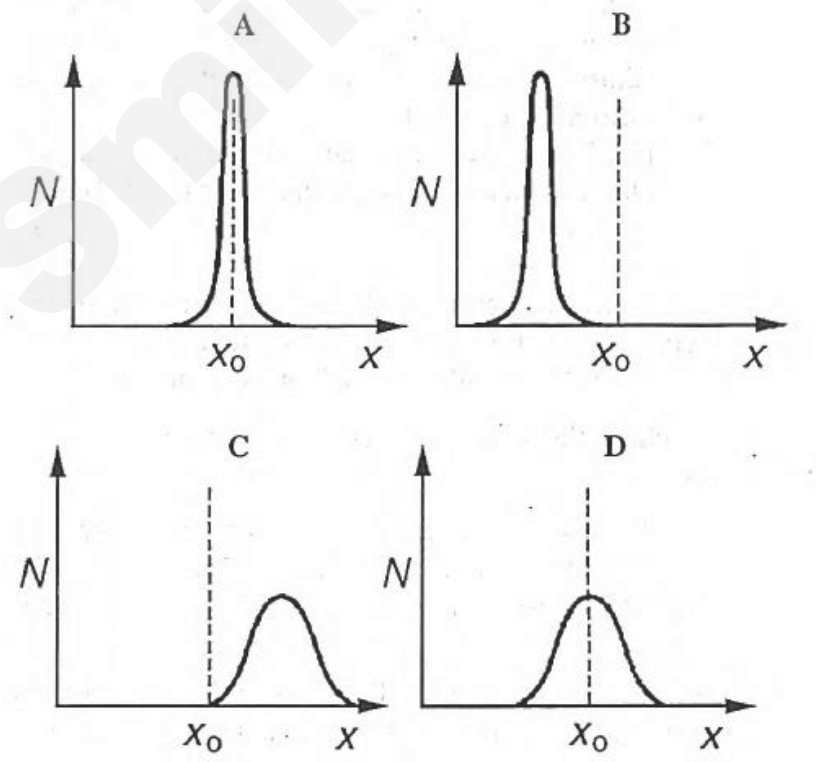
B 26 m s^{-1} , 30° north of east

C 15 m s^{-1} , 60° north of west

D 13 m s^{-1} , northwards

2 A quantity x is measured many times and the number N of measurements giving a value x is plotted against x. The true value of the quantity is x_o.

Which graph best represents precise measurements with poor accuracy?



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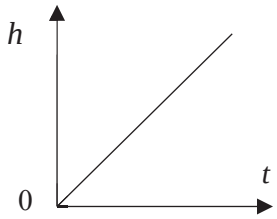
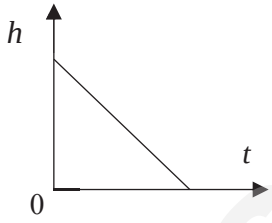
3 A brick falls vertically downwards from a tall building. Which of the following graphs represents the variation with time t of its height h **above** the ground if air resistance is negligible?

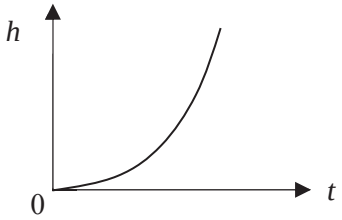
A



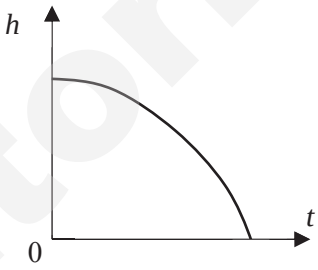
B



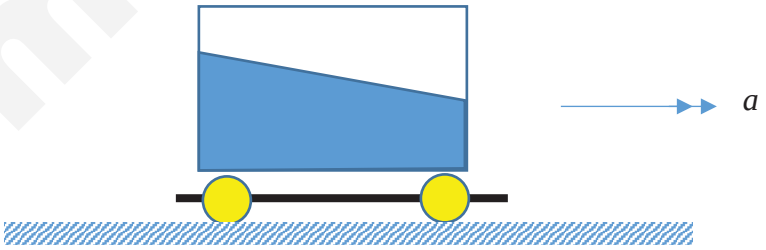
C



D



4 An aquarium partly filled with water accelerates along a level surface as shown below. The water surface makes an angle θ with respect to the horizontal. If the aquarium's acceleration is a while that due to gravity is g, deduce which of the following equations is correct. (Hint: consider forces acting on a single molecule at the water surface)



A $a = g\tan\theta$ **B** $a = g\sin\theta$ **C** $a = g\cos\theta$ **D** $a = g\cot\theta$

5 A spring obeying Hooke's Law has an unstretched length of 50 mm and a spring constant of 500 N m^{-1}. What is the energy stored in the spring when its overall length is 70 mm?

A 0.100 J **B** 0.600 J **C** 1.23 J **D** 100 kJ

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6 An object, immersed in a liquid in a tank, experiences an upthrust. What is the physical reason for this upthrust?

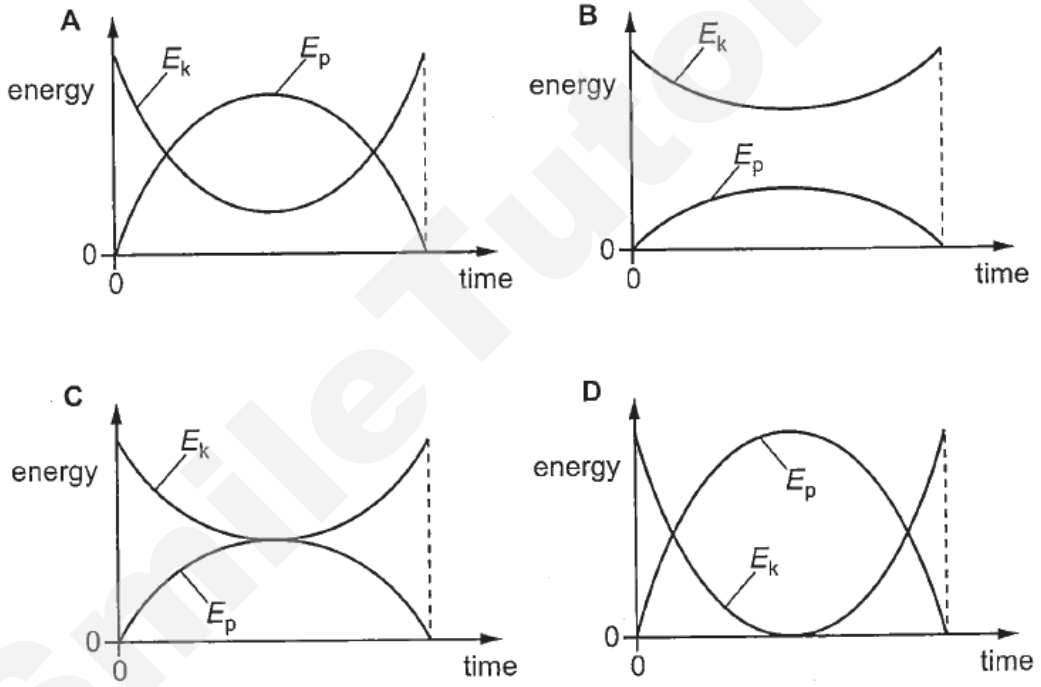
A The object has a uniform cross-sectional area.

B The object is denser than the liquid.

C The density of the object increases with depth in the liquid.

D The pressure in the liquid increases with depth.

7 A soccer ball is kicked at an angle of 60° above the horizontal. Which graph shows how the kinetic energy E_k and the gravitational potential energy E_p of the ball vary with time from the instant of impact until just before it reaches the ground? Ignore effects of air resistance.



8 A satellite of mass m is moving in a circular orbit of radius r about the earth of mass M. Which of the following is correct? G is the universal constant of gravitation.

	Total Energy	Kinetic energy
A	$-\frac{GMm}{2r}$	$\frac{GMm}{2r}$
B	$-\frac{GMm}{2r}$	$\frac{GMm}{r}$
C	$\frac{GMm}{2r}$	$\frac{GMm}{r}$
D	$\frac{GMm}{r}$	$\frac{GMm}{2r}$

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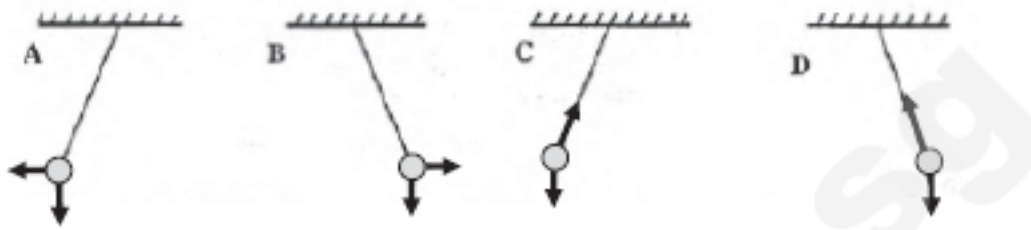
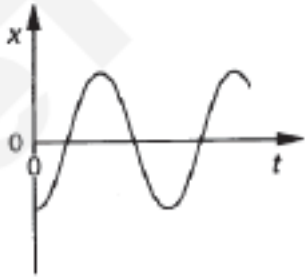
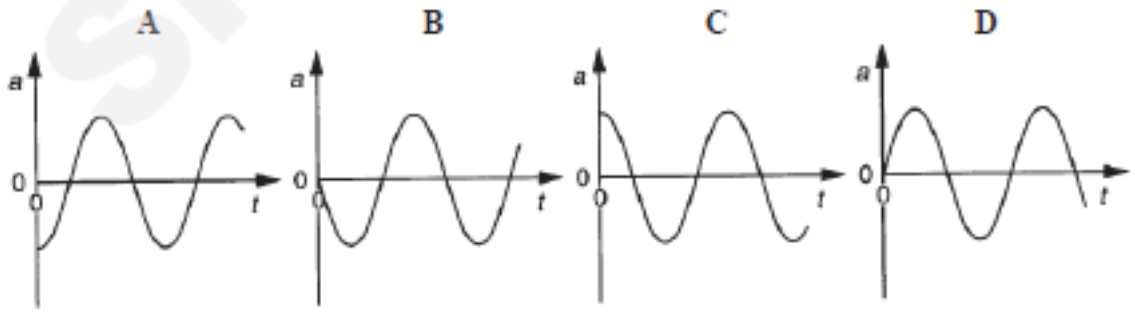
9 A passenger is sitting in a bus facing the direction in which the bus is travelling. A pendulum hangs down in front of him from the ceiling of the bus. The bus makes a turn to the right. Which of the following diagrams shows the position of the pendulum as seen by the passenger and the directions of the forces acting on it?



10 A body moves with simple harmonic motion about a point P. The graph shows the variation with time t of its displacement x from P.



Which graph shows the variation with time t of its acceleration a?



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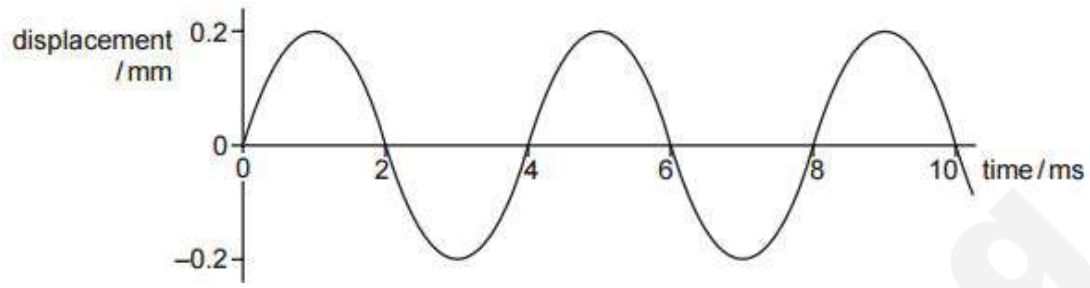
11 A sound wave moves through air. The variation with time of the displacement of an air particle due to this wave is shown in the graph below.



Which statement about the sound wave is correct?

A The frequency of the wave is 500 Hz.

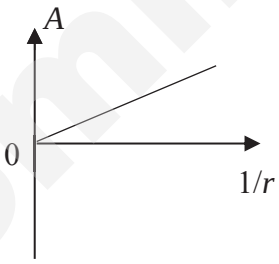
B The graph shows that sound is a transverse wave.

C The intensity of the wave will be doubled if its amplitude is increased to 0.4 mm.

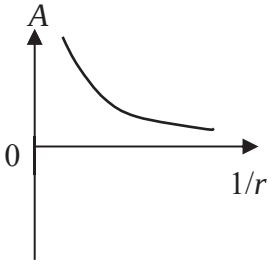
D The wavelength of the sound wave is about 1.32 m.

12 A point source of sound emits waves equally in all directions. Which graph shows the variation with $1/r$ of the amplitude A of the sound, where r is the distance from the source?

A



B



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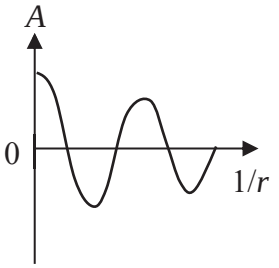

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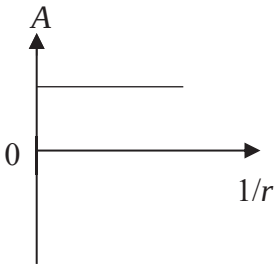

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13 An ideal gas of volume 1.5×10^{-3} m^3 and at pressure 1.0×10^5 Pa is supplied with 70 J of heat energy. The volume increases to 1.7×10^{-3} m^3, the pressure remaining constant. The internal energy of the gas is

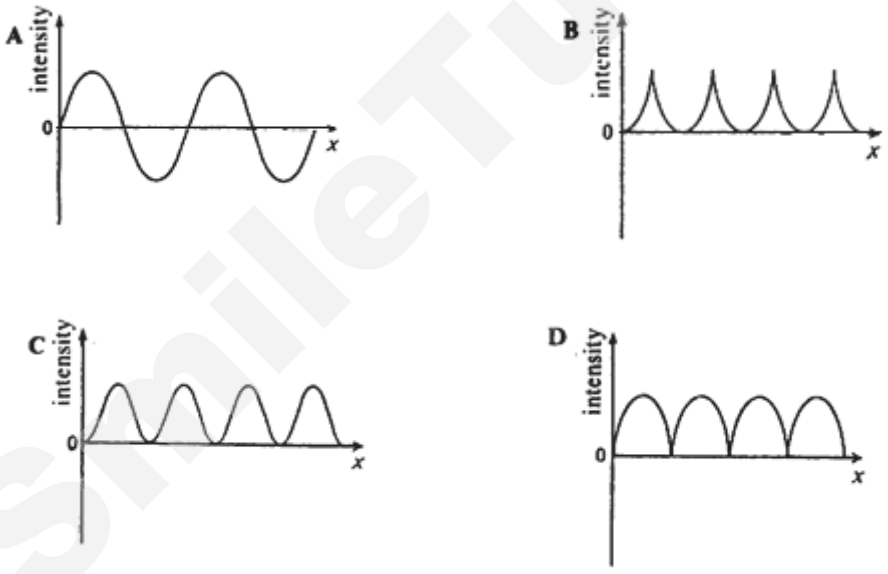
A decreased by 50 J.

B increased by 50 J.

C increased by 70 J.

D increased by 90 J.

14 Two coherent monochromatic waves of equal amplitude are brought together to interfere on a screen. Which one of the following graphs correctly represents the variation of intensity with position *x* across the pattern of fringes?



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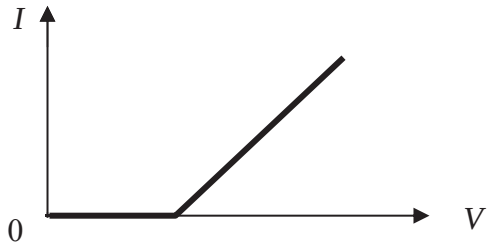
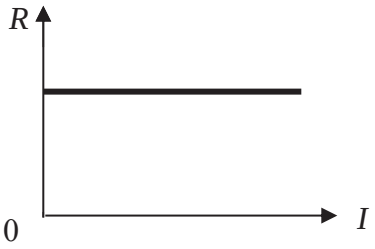
15 The diagram shows the relation between the current I in a certain conductor and the potential difference V across it.



Which graph shows the correct relation between its resistance R and current I?

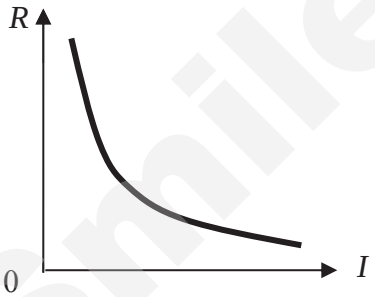
A



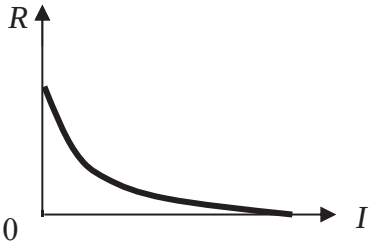
B



C



D



16 A copper wire has 2.0×10^{21} free electrons in 1.0 cm of its length. The drift speed of the electrons along the wire is 0.050 cm s^{-1}. What is the current in the wire?

A 0.16 A **B** 16 A **C** 160 A **D** 320 A

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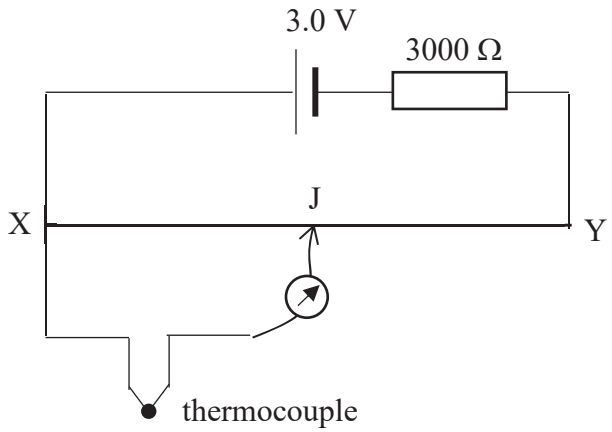
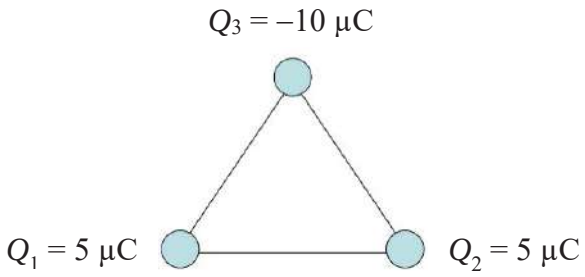
17



A thermocouple is connected across a potentiometer, and the jockey is slid along the metre bridge wire XY until balance point is reached. The balance length XJ is 80.1 cm. If the resistance of the bridge wire is 2.00 Ω, what is the e.m.f. of the thermocouple?

A 0.82 mV **B** 1.6 mV **C** 2.2 mV **D** 9.7 m

18 Three ping-pong balls are electrically charged and arranged in the plane of the page in an equilateral triangle as shown below. What is the direction of the force acting on the ping-pong ball charged with $Q_3 = -10$ μC?



A Towards the top of the page.

B Towards the bottom of the page.

C Towards the left.

D Towards the right.

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19 A linear conductor with current I_1 is placed along the axis of a solenoid, which carries current I_2.The magnetic force acting on the conductor is:

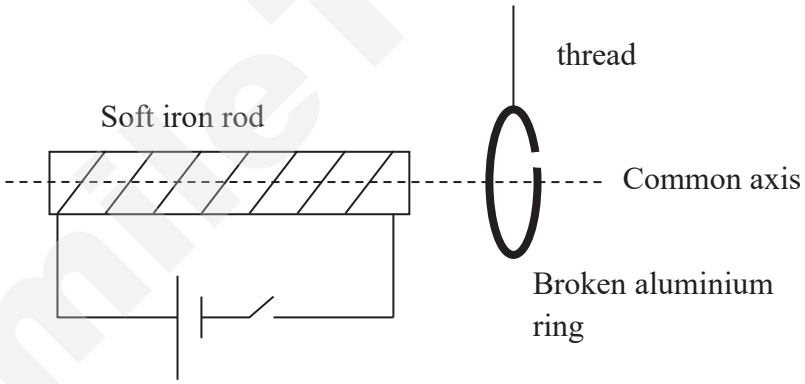
A zero;

B directly proportional to the product of currents I_1 and I_2, and inversely proportional to the radius of the solenoid;

C directly proportional to the product of currents I_1 and I_2, and inversely proportional to the square of the radius of the solenoid;

D directly proportional to the product of current I_1,current I_2, and the area of the solenoid

20 A solenoid is connected to a cell and switch. A soft iron rod is inserted into the solenoid. A broken aluminium ring is suspended from the thread with its axis aligned with that of the solenoid.



What will happen to the aluminium ring when the switch is closed?

A It will be repelled away from the solenoid.

B It will be attracted towards the solenoid.

C It will remain at rest.

D It will be repelled away from the solenoid before being attracted to it.

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21 An alternating potential difference is connected across a pure resistor and the frequency of the supply is varied, keeping the r.m.s voltage constant. The mean rate of production of heat in the resistor is

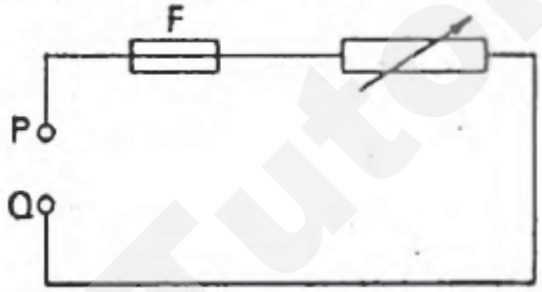
A proportional to frequency

B proportional to (frequency)^{½}

C inversely proportional to frequency

D independent of frequency

22 When an a.c. supply of 240 V r.m.s is connected to the terminals PQ in the circuit shown below, the fuse F breaks the circuit if the current just exceeds 13 A r.m.s.



When the a.c. supply is replaced with a 120 V d.c. source, an identical fuse breaks the circuit if the current just exceeds

A $\frac{13}{\sqrt{2}}$ A **B** 13 A **C** $13\sqrt{2}$ A **D** 26 A

23 Which of the following statements, referring to photoelectric emission, is always true?

A No emission of electrons occurs for very low intensity illumination.

B The number of electrons emitted per second is proportional to the frequency of the incident radiation.

C The number of electrons emitted per second is proportional to the product of the frequency of the incident radiation and the intensity of the incident radiation.

D No electrons will reach the collector if the magnitude of the decelerating potential difference between the emitting electrode and the collector is greater than the stopping potential.

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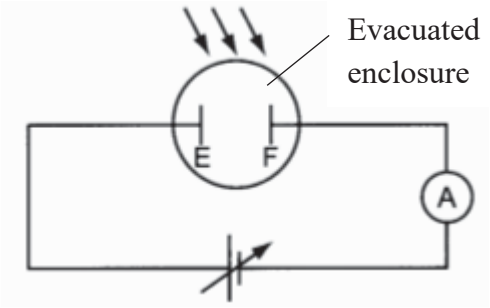
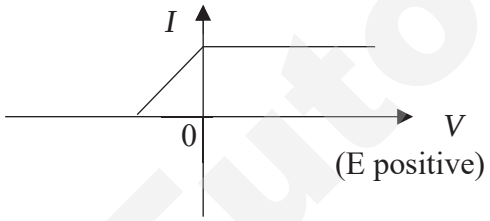
24 The diagram shows a circuit used for photoelectric emission experiments.



The two electrodes E and F are made of different metals. The work function of electrode E is ϕ_E, and the work function of electrode F is ϕ_F.

Current-voltage (*I*-*V*) characteristics are obtained when both electrodes are illuminated with monochromatic light.



Which of the following statements is correct?

A Electrons are emitted from E.

B Electrons are emitted from F.

C Electrons are emitted from both E and F.

D $\phi_E < \phi_F$

25 White light from a tungsten filament lamp is passed through sodium vapour and viewed through a diffraction grating. Which of the following best describes the spectrum which would be seen?

A Coloured lines on a black background

B Coloured lines on a white background

C Dark lines on a coloured background

D Dark lines on a white background

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26 An electron has an uncertainty of 5.0×10^{-12} m in its position. If its momentum is measured with an uncertainty of 1.00 %, what is its minimum kinetic energy?

A 3.8 MeV

B 6.6 MeV

C 38 MeV

D 66 MeV

27 All living matter contains carbon-14, which decays, according to the equation:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \mathrm{X} + \bar{\nu}$$

where $\bar{\nu}$ is an antineutrino. Identify X.

A electron **B** neutrino **C** proton **D** gamma ray

28 Two deuterium nuclei fuse together to form a Helium-3 nucleus, with the release of a neutron. The reaction is represented by

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy.}$$

The binding energies per nucleon are:

for $^{2}_{1}\mathrm{H}$ 1.09 MeV,

for $^{3}_{2}\mathrm{He}$ 2.54 MeV,

How much energy is released in this reaction?

A 0.36 MeV **B** 1.45 MeV **C** 3.26 MeV **D** 5.44 MeV

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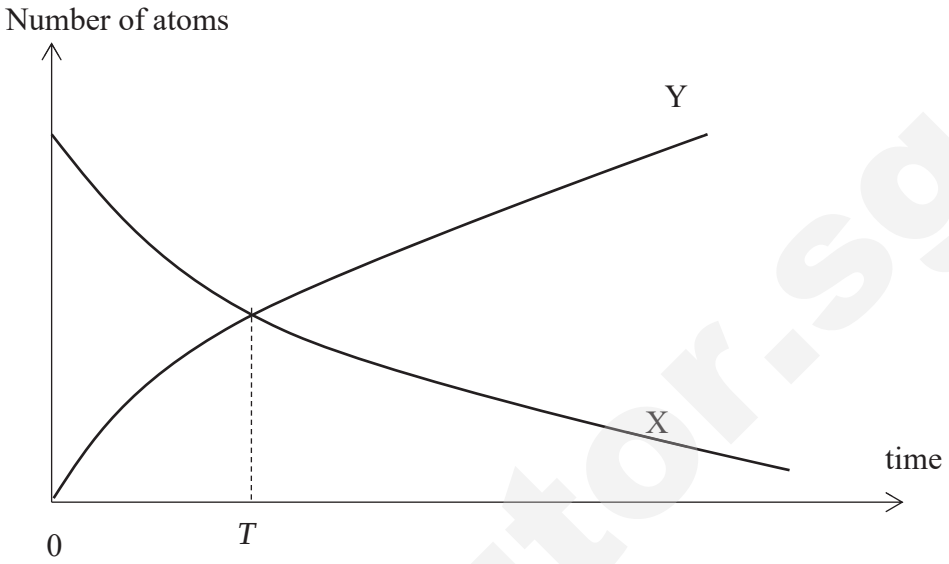
29 The graphs below represent the decay of a newly- prepared sample of radioactive nuclide X as it decays to a stable nuclide Y. The half-life of X is τ. The growth curve for Y intersects the decay curve for X at time T.



What is T?

A $\tau/2$ **B** $\ln(\tau/2)$ **C** τ **D** $\ln(2\tau)$

30 Which of the following samples of radioactive materials has the smallest rate of decay?

Sample	Half life / year	Amount / 10^{-7} mol
A	0.42	0.02
B	5.3	0.4
C	620	80
D	6200	200

******** END ********

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Name : _____ CT group: _____

VICTORIA JUNIOR COLLEGE
2017 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **9749/02**

Higher 2 **12 Sep 2017**

Paper 2 Structured Questions **TUESDAY**

8 am – 10 am

2 Hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total (max. 80)	

This document consists of **21** printed pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion,	$s = ut + (½)\,at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 A student set up the circuit shown in **Fig. 1** in order to determine the resistivity of the metal of the wire.

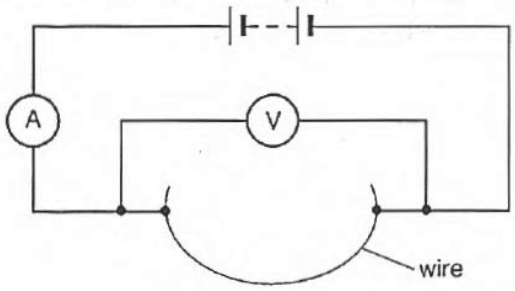

Fig. 1

(a) State a possible systematic error in this experiment and suggest a method to overcome this error.

……

……

…… [2]

(b) The following readings were obtained:

Reading of voltmeter, V	Reading of ammeter, I	Length of Wire, L	Diameter of Wire, d
1.50 ± 0.01 V	0.82 ± 0.01 A	63.2 ± 0.1 cm	0.48 ± 0.02 mm

(i) Show that the resistivity is given by $\rho = \dfrac{V\pi d^2}{4IL}$.

[1]

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(ii) Hence, or otherwise, calculate the resistivity of the metal of the wire together with its associated uncertainty.

Resistivity = (..…… ± ……) …….. Ω m [4]

(c) Suggest why an alloy of two metals has a higher resistivity than any of the two metals used in the alloy.

……

……

……

……

……..… [1]

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2 A cricketer throws a ball with an initial velocity u at an angle of 30° above the horizontal, at a height of 1.5 m above the ground. The ball returns to its initial height 3.0 s later.

(a) Neglecting air resistance, calculate

(i) the initial velocity u of the ball,

u = ……. m s^{-1} [2]

(ii) the maximum height *above* the ground to which it rises.

Maximum height = …… m [3]

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(b) In the space below, sketch a graph to show how the vertical component of the velocity of the ball varies with time during its flight, taking the upward direction as positive.
Mark on the graph the times at which

(i) the ball leaves the cricketer's hands (t_1),

(ii) it reaches its maximum height (t_2),

(iii) it returns to its initial height above the ground (t_3).

[2]

(c) Without carrying out any calculations, explain how air resistance would affect the maximum height reached by the ball if it was projected with the same initial velocity.

……

……

……

……

……

……[2]

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3 A 0.050 kg mass is attached to one end of an elastic string of unstretched length 0.50 m. The other end of the string is attached to a fixed support. The force constant of the elastic string is 40 N m^{-1}. The mass is rotated steadily on a smooth table in a horizontal circle of radius 0.70 m as shown in **Fig. 3.1**.



Plan View

Fig. 3.1

Fig. 3.2 shows the side view of the string and mass.

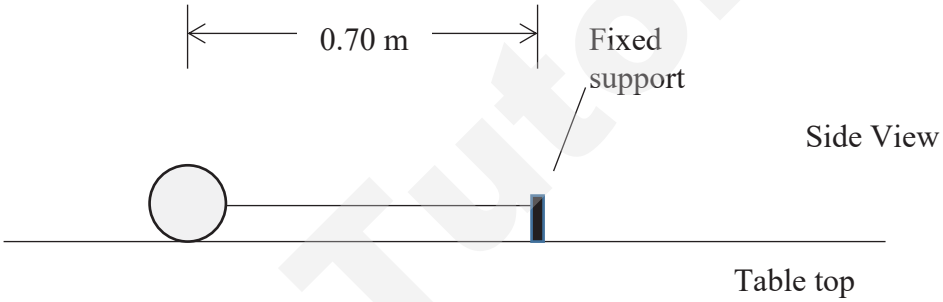

Fig. 3.2

(a) On **Fig. 3.2**, draw and identify the forces acting on the mass. [2]

(b) Calculate the magnitude of the resultant force acting on the mass.

Resultant force = ……. N [2]

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(c) Calculate the linear speed of the mass.

Linear speed = …….. m s^{-1} [2]

(d) Calculate the time taken for one revolution of the mass.

Time taken = …….. s [1]

(e) The mass is now rotated at a speed *v* in a vertical plane of radius *r*. Derive an expression for the minimum speed at the highest point of the circular path at which the string *just* becomes slack.

[2]

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4 **(a)** State why the interference that occurs between the light waves from identical filament lamps does not result in observable interference fringes.

……

……

……

……

…… [2]

(b) Two identical radio aerials P and Q are separated by a distance D. A sinusoidal radio signal of wavelength λ is received from an aircraft passing directly overhead at a speed v and height h along a line parallel to that between the aerials as shown in **Fig. 4**. The signals from the two aerials are added together and the resultant is recorded.

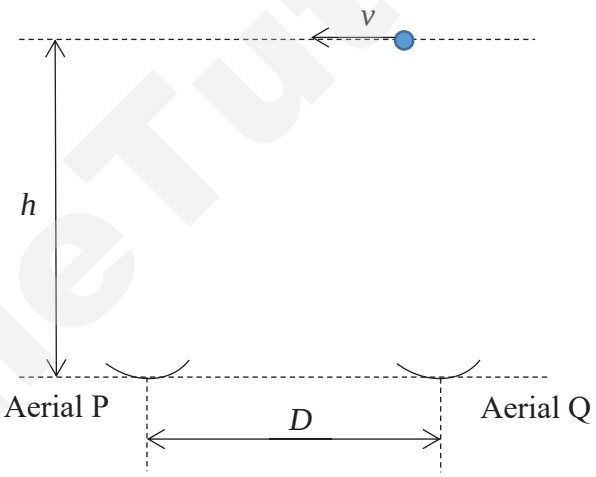

Fig. 4

(i) Explain why the intensity of the resultant signal fluctuates.

……

……

……

……

……

……[2]

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(ii) Deduce an expression for the minimum distance travelled by the aircraft in order to receive two successive maximum signals. Your expression should only contain the terms given in **(b)**. Assume that the height h is much larger than the distance D between the aerials.

[2]

(iii) Suggest two things which might interfere with the signals received by the aerials.

……

……

……

……

…… [2]

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5 The magnetic field in **Fig. 5** spans an area 1.50 m by 0.50 m. It points into the plane of the paper with a magnitude of 0.25 T. A metal rod RS slides to the left on a frictionless, fixed, light, conducting loop with a speed of 2.0 m s^{-1}. The resistance of the metal rod is 0.50 Ω, while the loop has negligible resistance.

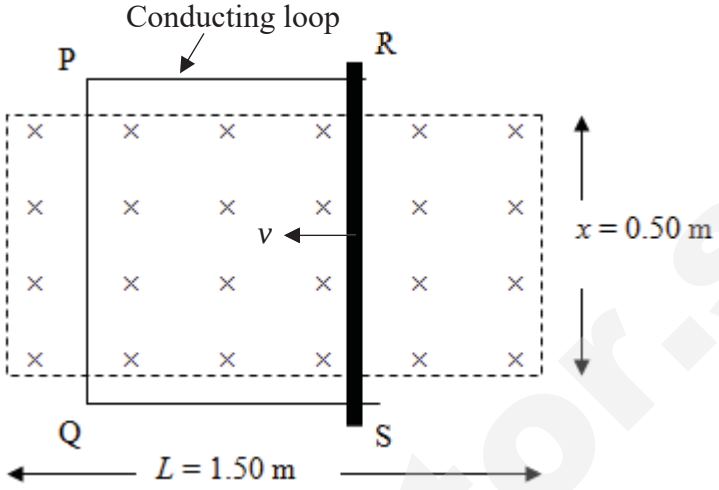

Fig. 5

(a) Calculate the induced e.m.f. in the moving rod.

Induced e.m.f. = ……. V [2]

(b) Calculate the induced current in the circuit and state its direction (clockwise or anti-clockwise) around the loop.

Induced current = …….. A [1]

Direction: …….. [1]

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(c) Explain why the conducting loop has to be fixed in position for your answer to **(b)** to be valid.

……

……

……

……

…… [3]

(d) Suppose now the loop is fixed in position. Suppose also that the resistance of the circuit is a very small value such that the induced current is very large, and that the position of RS and PQ are extremely close to each other. The other quantities are unchanged. Explain

(i) why your answer to **(a)** is no longer valid,

……

……

……

…… [1]

(ii) whether the induced e.m.f. will be larger or smaller than that in **(a)**.

……

……

……

……

…… [1]

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6 X-rays are produced when electrons are accelerated through a potential difference towards a metal target such as tungsten. **Fig. 6** shows a typical X-ray intensity spectrum that can be produced from an X-ray tube.

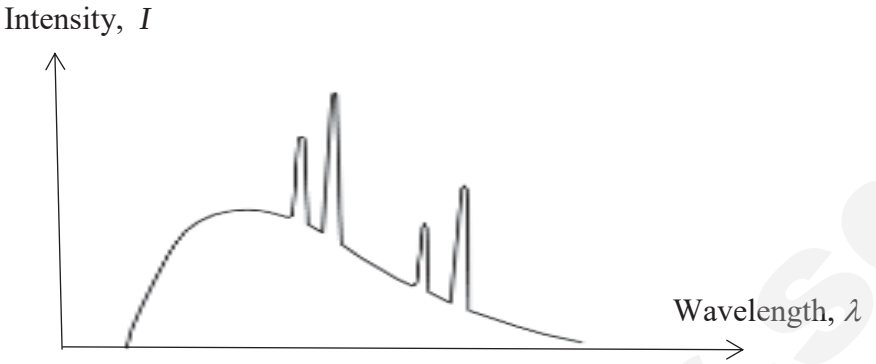

Fig. 6

(a) Explain the origins of the following features of **Fig. 6**:

(i) Characteristic lines

……

……

……

……

……

……

…… [3]

(ii) Cut-off wavelength

……

……

……

…… [1]

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(b) If the electrons are accelerated through a potential difference of 75.0 kV, determine the cut-off wavelength of X-rays that can be produced by the tube.

Cut-off wavelength = ……. m [2]

(c) Suppose now the potential difference used to accelerate the electrons is decreased. Sketch, in **Fig. 6**, the new spectrum obtained. [2]

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7 A head-on collision takes place between an α-particle and a stationary nitrogen nucleus. It results in the following nuclear reaction.

$$^{14}_{7}\mathrm{N} + ^{4}_{2}\mathrm{He} \rightarrow ^{17}_{8}\mathrm{O} + ^{1}_{1}\mathrm{H}$$

The masses of the **nuclei** involved are listed below.

$^{14}_{7}\mathrm{N}$	13.9993u
$^{4}_{2}\mathrm{He}$	4.0015u
$^{17}_{8}\mathrm{O}$	16.9947u
$^{1}_{1}\mathrm{H}$	1.0073u

(a) Name the particles represented by $^{4}_{2}\mathrm{He}$ and $^{1}_{1}\mathrm{H}$ respectively.

$^{4}_{2}\mathrm{He}$: …….. ; $^{1}_{1}\mathrm{H}$: ……. [1]

(b) Calculate the small change in mass, in kilograms, which takes place in this nuclear reaction.

Change in mass = …… kg [1]

(c) Use your answer to **(b)** to calculate the theoretical minimum kinetic energy needed by the α-particle to enable the nuclear reaction to proceed. Show your calculations clearly.

Minimum kinetic energy needed = …….. J [2]

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(d) Given that the masses of the proton and neutron are 1.0073 u and 1.0087 u respectively, calculate the binding energy per nucleon (in MeV) of the helium nucleus.

Binding energy per nucleon = …….. MeV [3]

(e) **(i)** Sketch a graph to show the variation with mass number of the binding energy per nucleon of different radioactive isotopes.

[1]

(ii) Use your graph in (e)(i) to explain how fission of heavy nuclei can lead to more stable nuclides.

……

……

……

……

……

…… [1]

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8 Last year, Ah Beng and Ah Lian tried to compare two cars. A manufacturer of the USA car claims fuel efficiency of 30 mpg (miles per gallon). The manufacturer of the European car states the fuel efficiency of 7.80 *l* /100 km (litres per hundred kilometers). (One kilometre is equivalent to 0.621 mile while a gallon is equal to 3.79 litres.)

(a) Determine which car is more efficient and by how much. Make your comparison in terms of litres per 100 km *(l* /100 km)

…….. [4]

This year, still undecided, Ah Beng noticed that the manufacturer of the European car improved the car's fuel efficiency so that it is now 15.38 km / *l*.

(b) Determine the percentage improvement in the European car's fuel efficiency.

Percentage improvement = …….. % [3]

Fig. 8.1 shows the variation with time of the speed of his car during a trip.

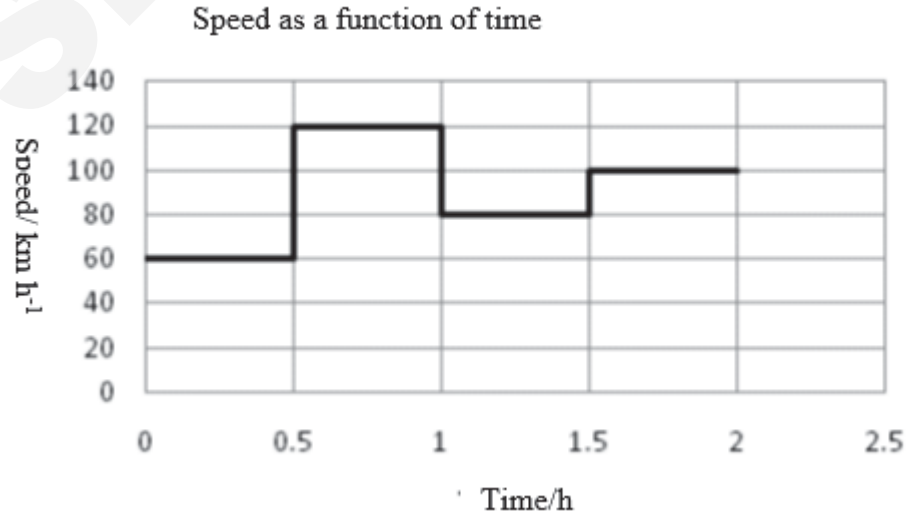

Fig. 8.1

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(c) **(i)** Determine the total distance travelled during this two hour trip.

Total distance travelled = ……. km [2]

(ii) Ah Lian says a feature of the graph does not appear to agree with reality. Identify it and explain why.

……...

……...

……..…[2]

Fig. 8.2 displays the air drag force on the car as a function of its speed.

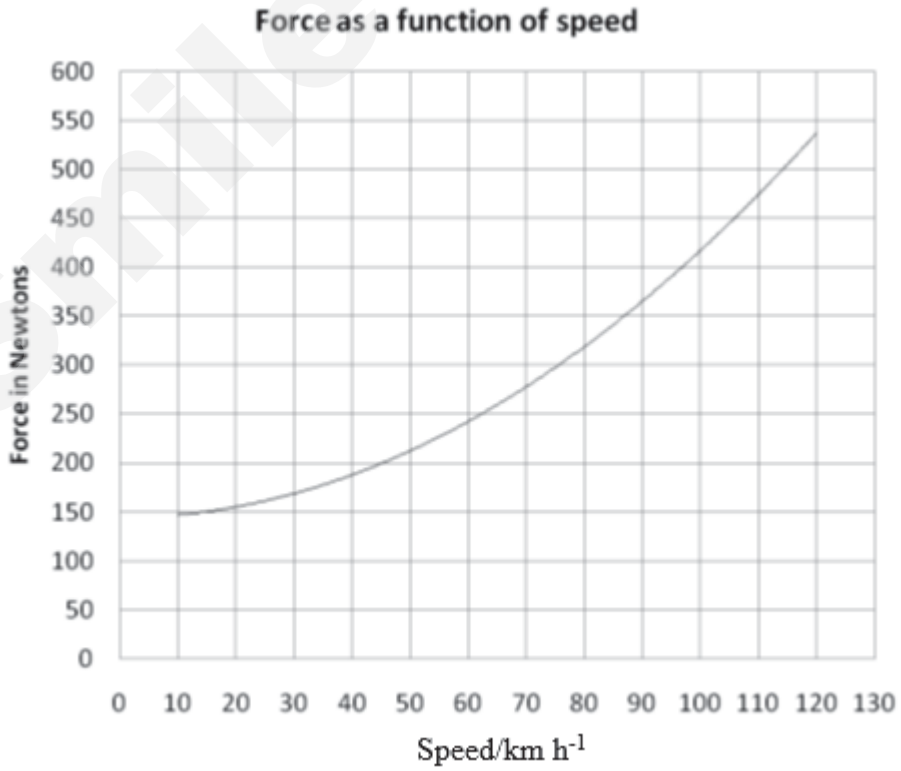

Fig. 8.2

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(iii) Estimate the total work done against the drag force on the car during the **first hour** of the trip.

Work done = ……. J [3]

Each litre of petrol has 35 MJ of energy. The engine efficiency as a function of the car's speed is shown on **Fig. 8.3**. Engine efficiency is defined as the ratio of work done to overcome air drag to the energy that can be generated from fuel consumed by the car.

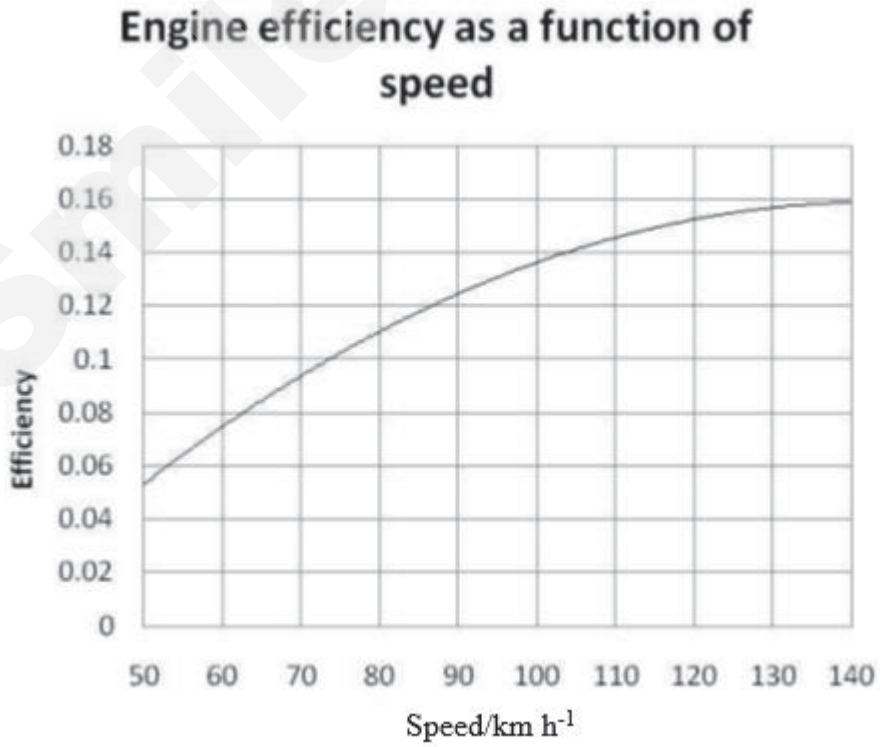

Fig. 8.3

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(iv) Calculate the total amount of petrol in litre used to overcome the air drag **during the first hour** of the trip.

Amount of petrol used = …….. *l* [3]

(v) Determine which part of the trip **over the first hour** the fuel was used more efficiently (least petrol used per kilometer travelled).

…….. [3]

*******END ******

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Name : _____ CT group : _____

VICTORIA JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/03**

Higher 2

18 Sep 2017

MONDAY

Paper 3 Longer Structured Questions

2 pm – 4 pm

2 Hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Total	

This question set consists of a total of **21** printed pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

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Formulae

uniformly accelerated motion,	$s = ut + (½)\,at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in this section in the spaces provided.

1

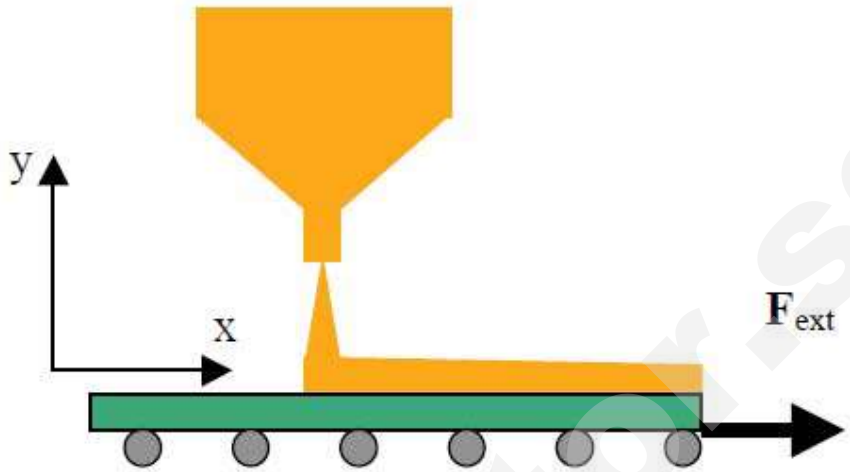

Fig. 1

Sand from a stationary hopper falls onto a moving conveyor belt at a rate of 5.00 kg s^{-1} as shown in **Fig. 1**. The conveyor belt is supported by frictionless rollers and moves at a constant speed of 0.75 m s^{-1} under the action of a constant horizontal external force $\boldsymbol{F}_{ext}$ supplied by the motor that drives the belt.
Calculate:

(a) the force of friction exerted by the belt on the sand;

Frictional force = ……. N [2]

(b) the external force $\boldsymbol{F}_{ext}$;

F_{ext} = ……. N [1]

(c) the power due to $\boldsymbol{F}_{ext}$;

Power = …….. W [2]

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(d) the rate of change of kinetic energy of the sand due to the change in its horizontal motion;

Rate of change of kinetic energy = ……. $J\ s^{-1}$ [2]

Compare and analyse the answers to **(c)** and **(d)**.

…….

…….[2]

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2 The Prius is a hybrid car that runs on both petrol and electricity. It has a mass of 1300 kg.

(a) Calculate the kinetic energy of a Prius that is moving at a speed of 60 kmh^{-1}.

Kinetic energy = ……. J [2]

(b) The power *P* required to overcome external forces opposing the motion of the Prius is given by the expression

$$P = 240v + 0.98v^3$$

(i) Calculate the magnitude of the external forces opposing the motion of the car when it is moving at a constant speed of 60 km h^{-1}.

Resistive forces = …… N [2]

(ii) Hence or otherwise, calculate the work done in overcoming the force in **(b)(i)** during a time of 3.0 minutes.

Work done = ……. J [2]

Prius' technology allows the hybrid car to convert the kinetic energy during braking into electrical energy and store it in a battery for use during acceleration.

(c) Suggest one advantage and one disadvantage of a fully electric car compared with a hybrid car.

……..

……..

…… [2]

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3

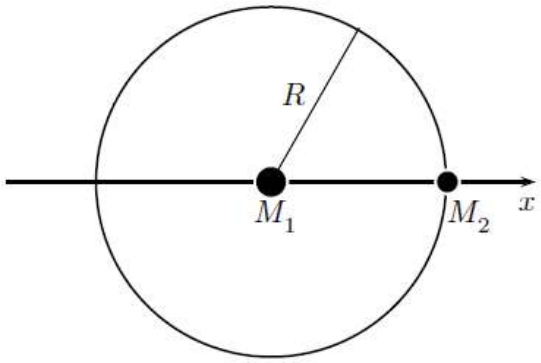

Fig. 3

M_1 and M_2 refer to masses of the Sun and the Earth respectively. Both orbit around their common centre of mass at angular velocity ω and with a period *T*. These orbits are *circular* to a good approximation, and the distance *R* between the Sun and the Earth is taken to be constant.

(a) Explain why the centre of the Earth's orbit can be assumed to be effectively the centre of the Sun.

……

…… [1]

(b) Estimate a numerical value for ω.

$\omega \approx$ …… rad s^{-1} [2]

(c) Show that ω and *R* are related by $\omega \propto R^{-\frac{3}{2}}$. Deduce an expression for the constant of proportionality.

…… [3]

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(d) **(i)** An object of mass *m* is located on the line joining the Sun and the Earth so that it also orbits the centre of the Sun with the *same* constant angular velocity ω. By considering forces acting on the mass *m*, write down two possible equations for the motion of the mass *m* about the centre of the Sun. Take the distance of the mass *m* from the Sun to be *x*. Express your answers in terms of M_1, M_2, R, x, G and ω where *G* is the universal gravitation constant.

[2]

(ii) State an assumption made when deriving the equations in **(i)**.

……..……

……..…… [1]

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4 Consider a cubical box of side l which contains N molecules, each of mass m, all moving horizontally with speed u at right angles to wall A. See **Fig. 4**.

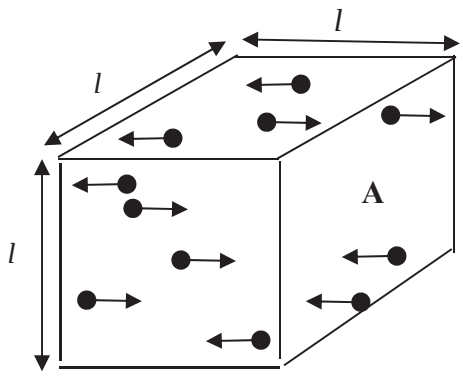

Fig. 4

When a molecule hits a wall, it bounces off with no loss of speed and travels in the opposite direction.

(a) Deduce

(i) the change in momentum of a molecule when it collides with a wall,

Change in momentum = …….. [1]

(ii) the time taken by one molecule between collisions with wall A,

Time taken = …… [1]

(iii) the force due to all the molecules colliding with wall A.

Total change in momentum per unit time = …….. [3]

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(b) Use your answer in **(a)** to show that the pressure p on wall A is given by $p = \frac{Mu^2}{V}$ where M is the total mass of all the molecules and V is the internal volume of the box.

[1]

(c) Give two reasons why the expression in **(b)** is not valid.

……..……..

……..……..

……..……..

……..……..…….[2]

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5 **(a)**

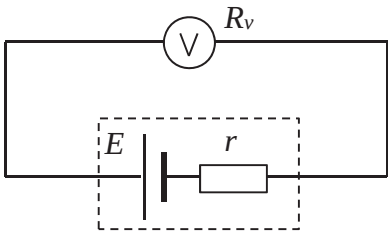

Fig. 5.1

A voltmeter is connected across the terminals of a cell of e.m.f. E = 2.0 V and internal resistance r. See **Fig. 5.1**. If the resistance of the voltmeter is R_v, write down an expression for the voltmeter's reading. Express your answer in terms of R_v, r and E.

……. [1]

(b) If r = 0.10 Ω, determine the minimum resistance that the voltmeter must have for its reading to be within 0.10 % of the e.m.f. E.

Minimum resistance required = ……. Ω [2]

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(c) **(i)**

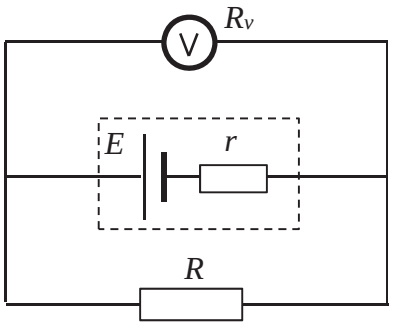

Fig. 5.2

The cell is now connected across a resistor R. (See **Fig. 5.2**).
Derive an expression for the reading of the voltmeter. Express your answer in terms of R_v, r, R and E.

…… [3]

(c) **(ii)** Calculate the voltmeter's reading if it just fulfills the condition in **(b)** and $R = 0.90\ \Omega$.

Voltmeter reading = ……. V [2]

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6 A flat metal coil used to produce a magnetic field for an electron beam experiment has 200 turns and a radius of 12.0 cm. The density D and resistivity ρ of the metal of the wire are 1.0×10^4 kg m^{-3} and 2.0×10^{-8} Ω m respectively. The wire has a radius of cross-section of 0.457 mm.

(a) Calculate the resistance of the coil.

Resistance = …… Ω [3]

(b) Determine the magnitude of a p.d. that is required to be applied across the ends of the flat coil to produce a magnetic field with a magnitude of 5.0×10^{-3} T at the centre of the coil.

p.d. required = …… V [3]

(c)

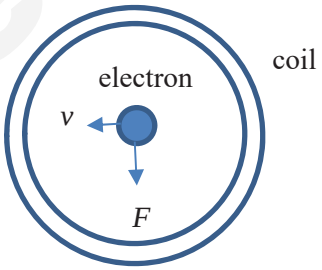

Fig. 6

Fig. 6 shows an electron travelling at 4.0×10^5 m s^{-1} being deflected as it moves through the coil. Calculate the magnetic force acting on the electron and deduce the direction of the magnetic field at the centre of the coil.

Magnetic force = …… N [2]

Direction of magnetic field = …….. [1]

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7 **(a)** 1.0 g of radioactive magnesium $^{23}_{12}Mg$ undergoes decay into sodium $^{23}_{11}Na$ with a half life of about 11.3 s.

(i) By writing down a nuclear equation for the decay, identify all the particles that are produced in this decay.

……. [2]

(ii) Calculate the initial rate of decay of magnesium nuclides .

Initial rate of decay = …… s^{-1} [2]

(b) To illustrate the effect of an electric field on the paths of α, β and γ radiations when travelling in a cloud chamber, a book contains a diagram similar to **Fig. 7**.

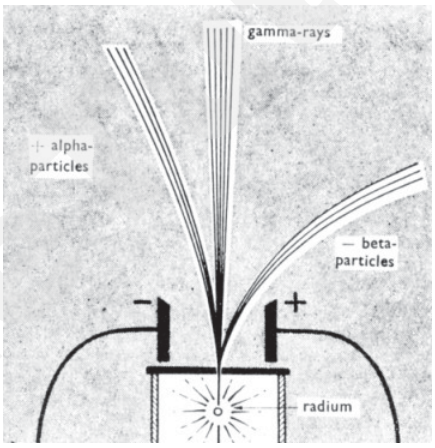

Fig. 7

Explain why

(i) no curvature of gamma radiation takes place.

…… [1]

(ii) the paths of the α and β curve when in the electric field. Identify the nature of the curve.

……

…… [2]

(iii) a pattern of tracks, such as that shown in **Fig. 7,** is not correct.

……

…… [2]

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Section B

Answer **one** question in this section in the spaces provided.

8

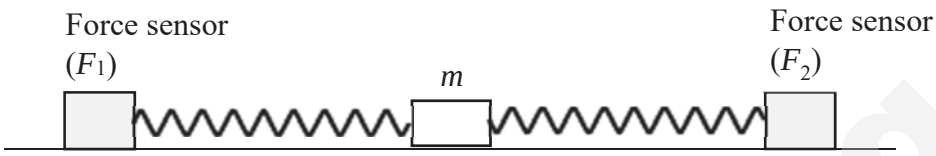

Fig. 8.1

A 0.200 kg mass is attached sideways to two electronic force sensors using identical springs of constant k. The force sensors are fixed in place. When the mass is at rest in the centre at equilibrium, each spring is stretched by a distance e = 0.150 m.
The mass is then displaced towards the right and then released, so that it oscillates horizontally on a frictionless surface.
The force sensor on the left side records the force F_1 exerted on it, which varies with time t according to **Fig. 8.2**.

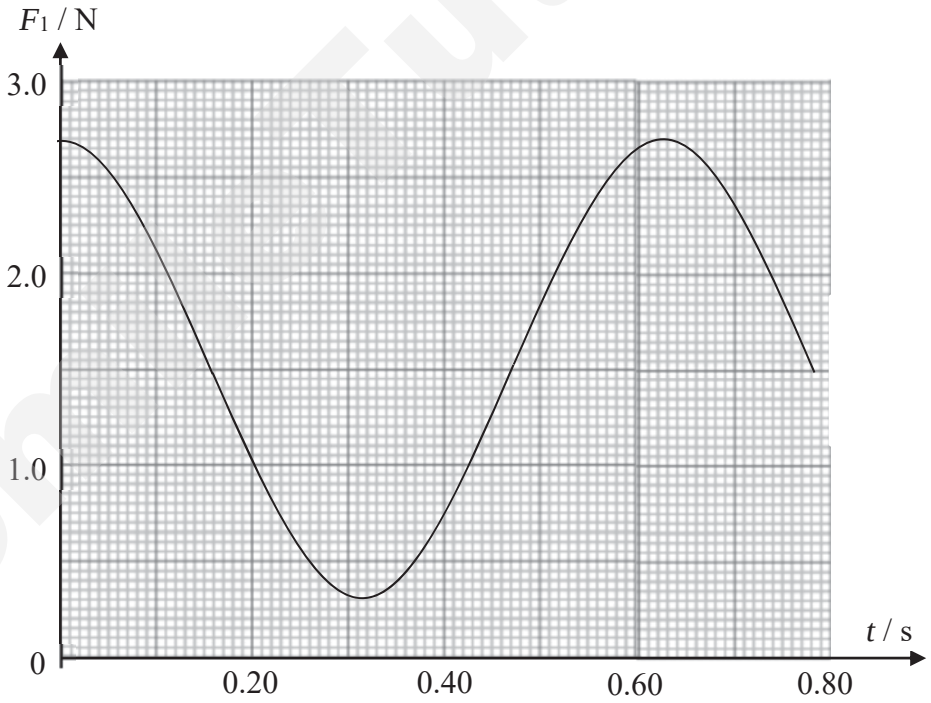

Fig. 8.2

(a) On **Fig. 8.2**, sketch the variation with time t of the force F_2 recorded by the sensor on the right.

[2]

(b) State the period T of the oscillation.

T = …….. s [1]

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(c) Calculate the effective force constant k_{eff} of the two spring system.

k = ……. N m^{-1} [2]

(d) Prove that the system executes simple harmonic motion.

[2]

(e) Calculate the force constant k of each spring.

k = ……. N m^{-1} [1]

(f) Determine the amplitude x_0 of the oscillation.

x_0 = …… m [2]

(g) Calculate the maximum speed of the mass.

v_0 = …… m s^{-1} [2]

(h) Calculate the maximum kinetic energy K_0 of the mass.

K_0 = …….. J [1]

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(i) Sketch a graph to show the variation with displacement x of the kinetic energy of the mass.

[2]

(j) Calculate the minimum elastic potential energy of the system.

Minimum elastic potential energy = …… J [2]

(k) Sketch graphs to show the variation with time of the kinetic energy K, the elastic potential energy U and the total energy E of the system. Include appropriate numerical labels.

[3]

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9 **(a)** **Fig. 9.1** represents the four lowest energy levels of an electron in the hydrogen atom.

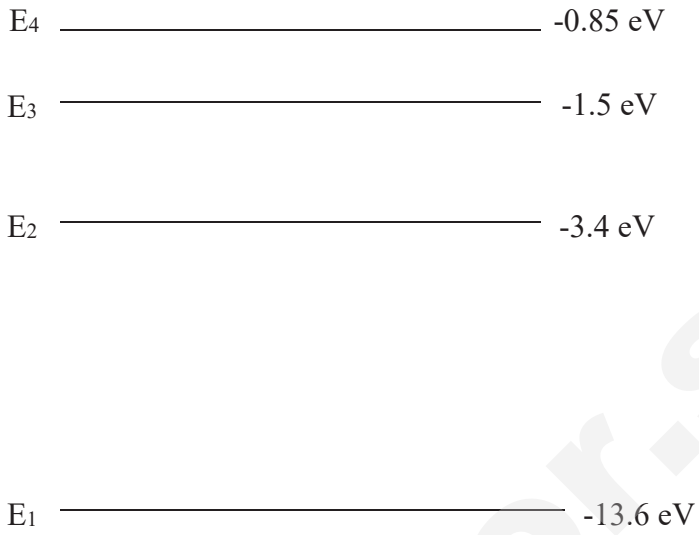

Fig. 9.1

(i) With the aid of a diagram, explain how an absorption line spectrum is produced.

…….

…….

…….

…….

…….

…….

…….

……. [4]

(ii) If the hydrogen atoms are originally in the ground state, draw, on **Fig. 9.1**, all the possible transitions that produce the absorption spectrum. [1]

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(iii) If the atoms are originally in excited states, draw, on **Fig. 9.2**, all the possible transitions that produce emission lines. [1]

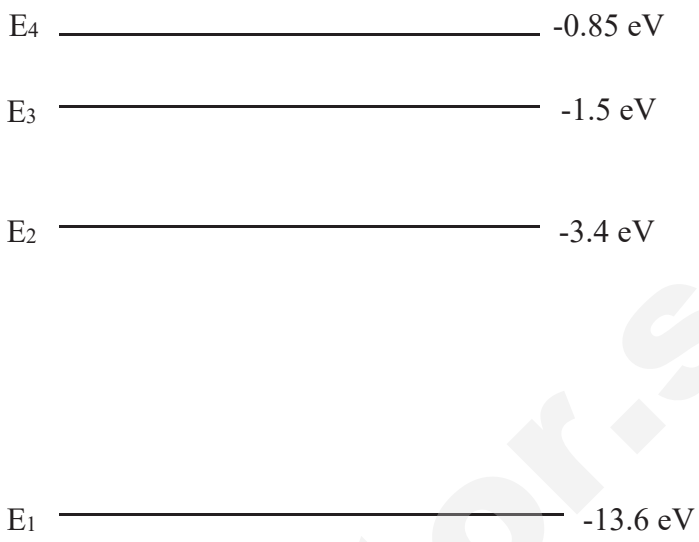

Fig. 9.2

(iv) State the ionisation energy of the hydrogen atom.

..... [1]

(v) State and explain what happens when mono-energetic electrons with energy greater than the ionisation energy in **(iv)** bombard hydrogen atoms originally in their ground state.

.....

.....

.....

.....

.....

.....

..... [2]

(b) **(i)** X-ray emission is often said to be the inverse of the photoelectric effect. Explain.

.....

..... [1]

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(ii) An X-ray spectrum of molybdenum is shown in **Fig. 9.3**.

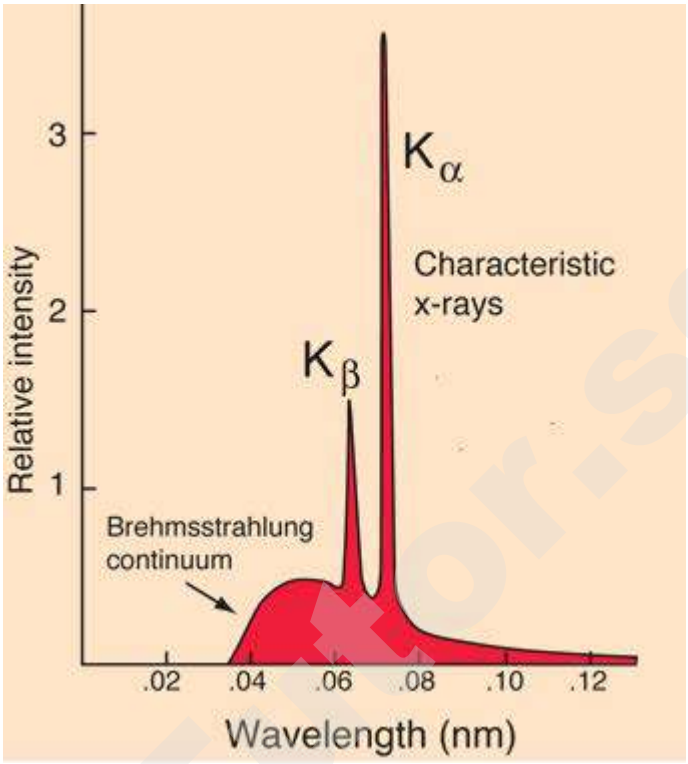

Fig. 9.3

1 Using **Fig. 9.3**, estimate a value for the wavelength that corresponds to the most energetic X-ray photon.

Estimated wavelength = ... nm [1]

2 Explain how the wavelength in **1** is different from that of the de Broglie wavelength of electrons that are used to produce the X-rays.

.....

.....

..... [1]

(c) The accelerating p.d. in an X-ray tube is increased. State and explain whether this will affect the following:

(i) Intensity of the X-radiation.

.....

.....

..... [2]

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(ii) Wavelength of the characteristic lines.

.....

.....

..... [2]

(d) State and explain whether the following will affect the intensity of X-radiation:

(i) Increasing the tube current.

.....

.....

..... [2]

(ii) Increasing the time taken to heat up the filament of the X-ray tube (This is called the exposure time. Note that X-ray tubes are usually switched on for a very short time).

.....

.....

..... [2]

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Apparatus for Question 1

1. retort stand with boss and clamp
2. brick
3. spring
4. 450 g mass (inclusive of holder)
5. stopwatch
6. meter rule

Apparatus for Question 2

1. Retort stand with two bosses
2. Two smooth nails with split corks
3. 50g slotted mass hanger
4. Spring
5. Wooden beam with holes drilled at the middle and one end.
6. Metre rule and set square
7. Brick to stabilise the retort stand
8. 20 cm string
9. Two 50 cm strings
10. Scissors

Apparatus for Question 3

1. Resistor labelled R1 (47 Ω)
2. Resistor labelled R2 (220 Ω)
3. Nine carbon film resistors, each with resistance value shown (33 Ω, 47 Ω, 100 Ω, 150 Ω, 220 Ω, 330 Ω, 470 Ω, 560 Ω, 680 Ω)
4. One dry cell (1.50 V)
5. Digital voltmeter capable of measuring voltages in the range 0–2 V
6. Milliammeter capable of measuring currents in the range 0–20 mA
7. Eight connecting leads with crocodile clips

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VICTORIA JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/04**

Higher 2 **29 Aug 2017**

TUESDAY

Paper 4 Practical Test **2 hours 30 minutes**

Candidates answer on the Question Paper.
Additional Materials: As listed on the Confidential Instructions.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	

This question set consists of a total of **12** printed pages.

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1 This investigation is on the oscillation of a mass on a spring.

(a) (i) Stabilise the base of the retort stand with the brick provided. Attach a spring to the clamp. Measure and record the natural length of the spring using the meter rule.

L = …… [1]

(ii) Attach the 450 g mass inclusive of mass holder to the other end of the spring vertically and lower it gently until the equilibrium position is attained. Measure and record the length of the extended spring.

L' = ……..... [1]

(iii) Calculate the spring constant k.

Spring constant k = ……..[2]

(iv) Displace the mass slightly downwards and release it so that it performs small oscillations. You will have to get a good set of timings in order to determine the period of oscillation T.

T = …… [2]

(v) Using **(a)(iii)**, **(a)(iv)**, calculate a value for the mass.

Calculated mass = ……. [2]

(vi) Suggest why there is a discrepancy in the result obtained in **(a)(v)** when compared with the stated value of 450 g of the mass.

……..

……..

……..

……. [2]

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(vii) State and explain one positive and one negative effect on the experimental results of oscillating a mass significantly greater than 450 g.

……..

……..

……..

……..

……..

……. [2]

(b) A meter rule is clamped vertically using another retort stand. The mass, which is suspended at the bottom of a different spring, is displaced downwards from its equilibrium position and then released so that it performs vertical oscillations next to the meter rule.

As time passes, the amplitude of oscillations is observed to decrease. The amplitude A of oscillations is measured in relation to n, the number of oscillations.

The graph of how ln A varies with the number of oscillations n is shown in **Fig. 1**. Using the graph, *estimate* the number of oscillations that corresponds to the amplitude that has reduced to half of the original value. [3]

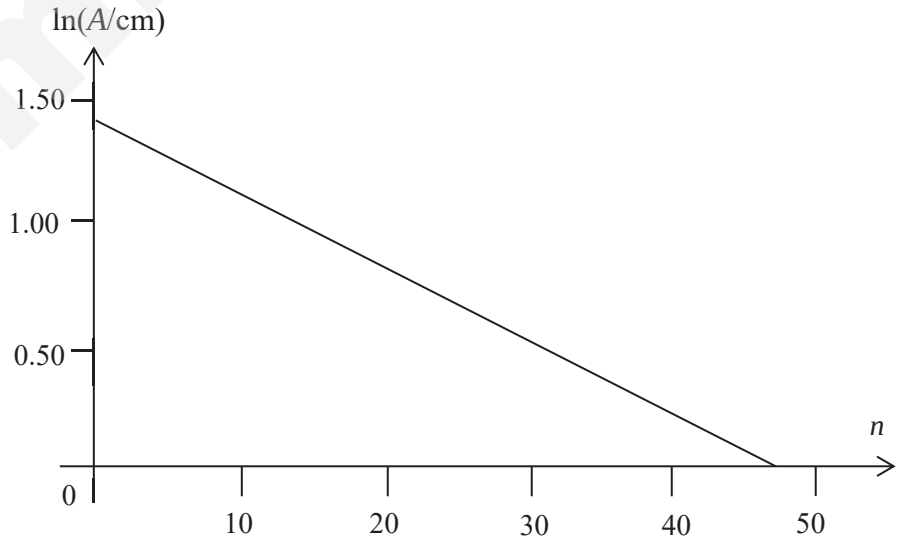

Fig. 1

[Total: 15 marks]

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2 This investigation considers the equilibrium of forces acting on a wooden beam.

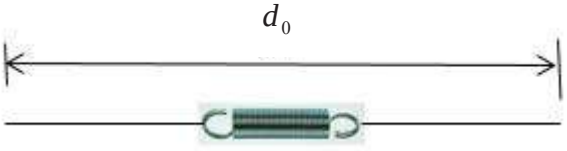

Fig. 2.1

(a) Tie the two strands of 50 cm thread to the two ends of the spring as shown in **Fig. 2.1**. The length of d_0 should be about 60 cm. Measure d_0.

d_0 = ... [1]

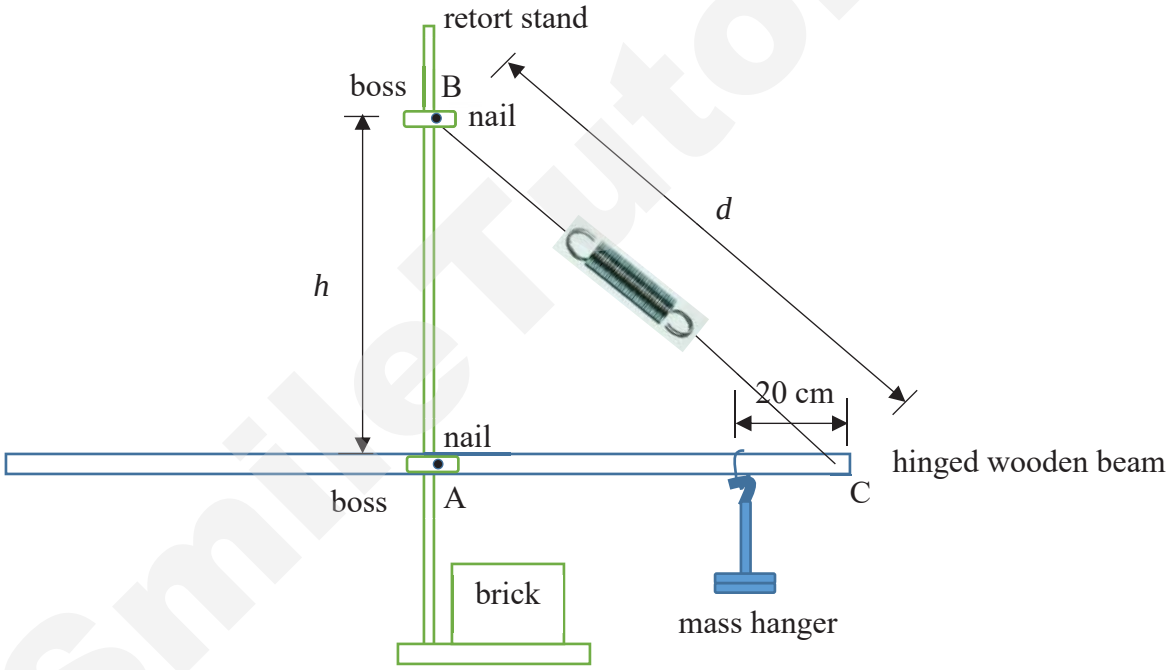

Fig. 2.2

(b) Set up the apparatus shown in **Fig. 2.2**, taking care to stabilise the retort stand with a brick.

(c) Suspend the 50 g mass hanger from a loop of string at 20 cm from C on the wooden beam. Carefully move the boss at B up or down the retort stand until the wooden beam is horizontal. Measure and record *d*, the distance BC, in **Fig. 2.2**.

d = ... [1]

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(d) Using your answers from (a) and (c), calculate the percentage uncertainty in $\frac{d_0}{d}$.

Percentage uncertainty = …….. [1]

(e) Measure and record height h from the nail at point A to the nail in the boss at B as shown in **Fig. 2.2**.

h = …… [1]

(f) Steps **(c)** and **(e)** are repeated for a further six values of m, the total mass of the hanger and slotted weights. These six readings have been measured and are recorded in the table below.

Calculate and fill in the table, the value of $(1-\frac{d_0}{d})h/\text{cm}$ for the 100 g mass. Take d_0 = 58.5 cm.

m/g	h/cm	d/cm	$(1-\frac{d_0}{d})h/\text{cm}$
350	55.0	69.5	8.71
300	53.5	68.0	7.47
250	52.2	66.5	6.28
200	49.2	65.0	4.92
150	45.5	63.9	3.85
100	44.0	62.5	

[1]

(g) The equation that relates h, d, d_0 and m is

$$\left(1-\frac{d_0}{d}\right)h = mk$$

where k is a constant.

(i) Plot the point corresponding to the mass m = 100 g obtained from **(f)** on the graph in **Fig. 2.3**. [1]

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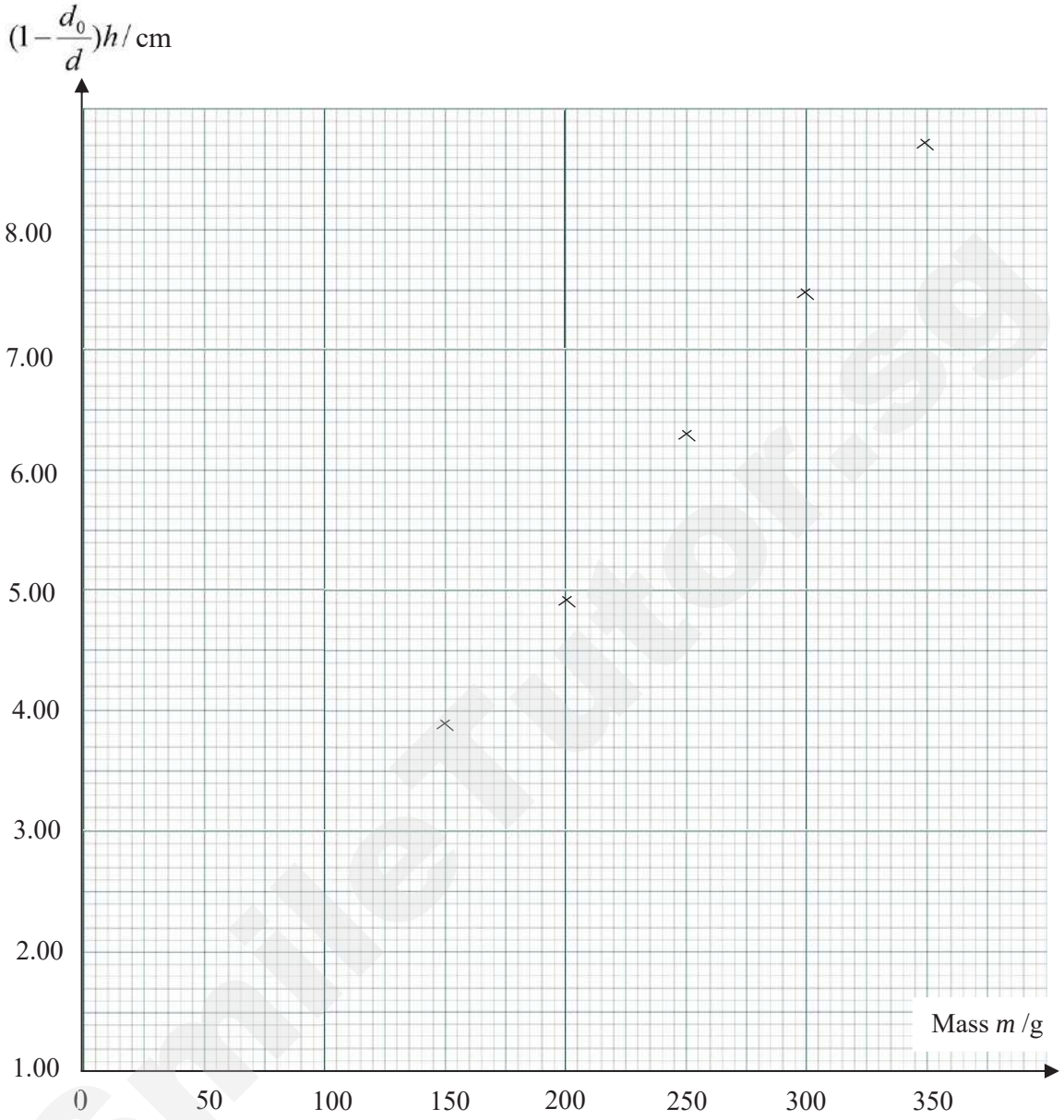

Fig. 2.3

(ii) Calculate the value of k, giving its unit.

k = ... [2]

[Total: 8 marks]

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You may not need to use all of the materials provided.

3 In this experiment you will measure the current I through a resistor $\mathbf{R_3}$ as its resistance is changed.

(a) (i) Use the voltmeter to measure the e.m.f. E of the power supply.

E = ... [1]

(ii) Connect the circuit shown in **Fig. 3.1**. $\mathbf{R_1}$ and $\mathbf{R_2}$ are labelled, and $\mathbf{R_3}$ may be chosen from any one of the remaining resistors. Each resistor carries a label indicating its resistance.

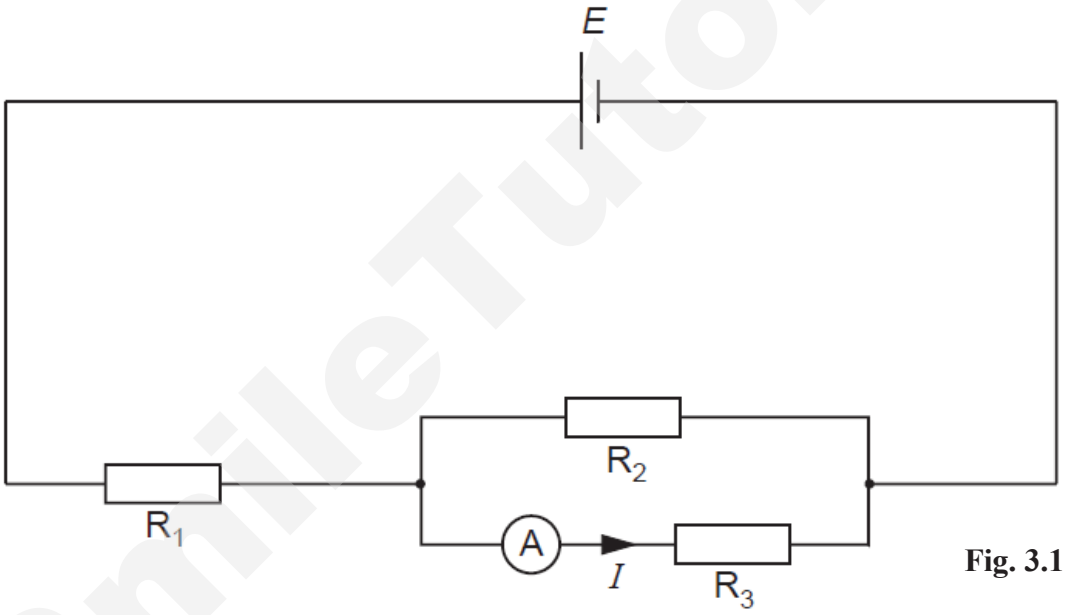

Fig. 3.1

(b) The relationship between I and R_3 is

$$\frac{1}{I} = \left(\frac{R_1 + R_2}{ER_2}\right)R_3 + \frac{R_1}{E}$$

where R_1 is the resistance of the resistor $\mathbf{R_1}$, R_2 is the resistance of the resistor $\mathbf{R_2}$, and E is the e.m.f. of the power supply.

By taking sufficient appropriate measurements, plot a suitable graph to determine the values of R_1 and R_2, showing all necessary calculations.

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Records

[7]

Graph and calculations

R_1 = ……..……

R_2 = …… [7]

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(c) Comment with justification whether there are any anomalous data in your results.

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…… [1]

(d) **(i)** Identify a significant source of error. Explain how this error affects your results.

……..

……..

……..

…… [1]

(ii) Suggest an improvement that could be made to the experiment and explain how it addresses the error/limitation in **(d)(i)**. You may suggest the use of other apparatus or different procedures.

……..

……..

…… [1]

(e) If R_1 and R_3 are constant and R_2 instead is the variable quantity, suggest the graph to plot to enable the values of R_1 and R_3 to be determined. Explain.

……..……..

……..……..

……..…… [2]

[Total: 20 marks]

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4 Direct current (d.c.) motors are characterised by some specifications, such as their stall torque and no-load speed when operated at a nominal fixed supply voltage. Such a motor can be used to raise an appropriate mass over a certain height.

The stall torque is the maximum torque that the motor can exert, when its rotational speed is zero.

The no-load speed is the maximum rotational speed of the motor axle when no load is attached to it, i.e. when the torque is zero.

It is known that the torque τ and rotational speed ω of the motor axle are related linearly by the equation

$$\tau = -k\omega + \tau_S$$

where k is a constant and τ_S is the stall torque.

Design an experiment to determine the stall torque and no-load speed of a low-power d.c. motor operating on a fixed supply voltage. You are provided with some masses for the experiment. You may also use any of the other equipment usually found in a physics laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the torque exerted by the motor axle and its angular speed are determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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Oscillation of mass on a spring

Marking Scheme of Q1

Question	Answer	Code	Marks
1(a)(i)	MMO Value of L to 1 d.p. in cm	M1	1
1(a)(ii)	MMO Value of L' to 1 d.p. in cm	M2	1
1(a)(iii)	MMO $x = L' - L$ calculated, ACE $F = kx$, Value of k to 2 or 3 s.f. with unit	M3 A1	1 1
1(a)(iv)	MMO Time ≥ 10.0 s, with repetition PDO Period T calculated to the appropriate number of s.f. with unit	M4 P1	1 1
1(a)(v)	ACE $T = 2\pi\sqrt{\frac{m}{k}}$ ACE Mass m calculated correctly to the appropriate number of s.f. (2 or 3 s.f.) with unit	 A2 A3	 1 1
1(a)(vi)	ACE Any two of the following: -Uncertainty in measurement of extension leading to inaccurate k -Spring may not obey Hooke's law hence affect k -Period T inaccurate due to human errors	A4 A5	1 1
1(a)(vii)	ACE A heavier mass will cause the oscillations to be slower, yielding a smaller percentage uncertainty in the period. However, it may extend the spring to the point where Hooke's Law is not obeyed.	A6 A7	1 1
1(b)	ACE $ln(A_0/2) = mn + ln(A_0)$ *where m = gradient* PDO $lnA_0 - ln2 = mn + lnA_0$ gradient calculated and y-intercept from graph ACE $n = 23$ n to nearest integer (accept between 20 and 26) or to 1 decimal place	A8 P2 A9	1 1 1

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MARKING SCHEME FOR QUESTION 2

Question	Answer	Code	Marks
2(a)	MMO d_0 recorded to 1 d.p. in cm (d_0 = 58.5 cm)	M1	1
(c)	MMO d recorded to 1 d.p. in cm with unit (d = 60.0 cm to 64.0 cm)	M2	1
(d)	ACE Percentage uncertainty of d_0/d correctly calculated to 2 s.f. 2 mm $\leq \Delta d \leq$ 5 mm but Δd_0 = 1 mm or 2 mm	A1	1
(e)	MMO h recorded to 1 d.p. in cm with unit (h = 40.0 cm to 44.0 cm)	M3	1
(f)	ACE Value of $(1- d_0/d)h$ correctly calculated to 3 s.f. for 100 g mass	A2	1
(g)(i)	PDO Point plotted correctly	P1	1
(g)(ii)	ACE Gradient – the hypotenuse of the triangle sufficiently large (i.e. must be greater than half the length of the drawn line.) Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (i.e. do not allow for $\Delta x/\Delta y$).	A3	1
	ACE Value of k calculated correctly with units. k = (0.0218 to 0.0254) cm g^{-1} = (0.218 to 0.254) m kg^{-1}	A4	1

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MARKING SCHEME FOR Qn 3

Question	Answer	Code	Marks
3(a)(i)	MMO Measurement of e.m.f. of power supply with unit	M1	1
3(b)	MMO Measurements Two marks for six sets of readings for I and R_3, 1 mark for 5 sets and zero marks for 4 sets or fewer	M2	2
	MMO Repetition of measurements for current	M3	1
	MMO Quality of data (Graph) Judge by scatter of points about the best fit line. Trend must be correct. At least 5 plots are needed for this mark to be scored.	M4	1
	PDO Column headings Each column heading must contain a quantity and a unit where appropriate. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit (i.e. solidus is expected, but accept, for example, I (A)). .	P1	1
	PDO Consistency of presentation of raw readings All values of I must be given to the same number of decimal places.	P2	1
	PDO Table: calculated quantities Significant figures Apply to $\frac{1}{I}$ only. If I is given to 3 sf, then accept $\frac{1}{I}$ to 3 sf. If I I is given to 4 sf, then accept $\frac{1}{I}$ to 4 sf.	P3	1

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Question	Answer	Code	Marks
	PDO (Graph) Axes Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. There should not be more than three large squares between axis labels. Scales must be chosen so that the plotted points must occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity which is being plotted.	P4	1
	PDO Graph: plotting of points All observations must be plotted. Check 3 plots at random. Ring and check a wrong plot. Tick if correct. Work to an accuracy of half a small square.	P5	1
	PDO Graph: trend line Line of best fit (must be 5 or more plots) Judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.	P6	1
	ACE Gradient The hypotenuse must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).	A1	1
	ACE y-intercept The value must be read to the nearest half square. The value can be calculated using $y = mx + c$.	A2	1
	ACE R_1 must be in range 40.0 to 90.0 Ω. Value for R_1 obtained from y-intercept x E. 2 or 3 sf. Unit required	A3	1
	ACE Should be (220 ± 80) Ω for R_2. Method of working must be correct. 2 or 3 sf. Unit required.	A4	1

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Question	Answer	Code	Marks
3(c)	MMO Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment on absence of anomalous data.	M5	1
3(d)(i)	ACE 1 point for each significant source of error and explanation. (resistor value of R_3 may not be exactly as stated on label; overheating of circuit affecting resistor values; possible fluctuation of current values)	A5	1
3(d)(ii)	ACE Improvements must be related to chosen source of error. (pre-determine R_3 values before experimentation; switch off circuit when measurements are not being made; ensure no loose connections or use a cell that is not too new or too old so that electrical discharge is more regular)	A6	1
3(e)	ACE $\frac{1}{I} = \left(\frac{R_1 + R_2}{ER_2}\right)R_3 + \frac{R_1}{E}$ can be rewritten as $\frac{1}{I} = \frac{R_1 R_3}{E}\left(\frac{1}{R_2}\right) + \left(\frac{R_3}{E} + \frac{R_1}{E}\right)$. A graph of $\frac{1}{I}$ can be plotted against $\frac{1}{R_2}$ which will yield $\frac{R_1 R_3}{E}$ as the gradient and $\left(\frac{R_3}{E} + \frac{R_1}{E}\right)$ as the vertical intercept. R_1 and R_3 can then be solved using simultaneous equations. *[1 mark for rewriting correct equation and another for determining the gradient and vertical intercept]*	A7	2

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Planning Question for 2017 Preliminary Exam 9749/4.

Direct current (d.c.) motors are characterised by some specifications, such as their stall torque and no-load speed when operated at a nominal fixed supply voltage. Such a motor can be used to raise an appropriate mass over a certain height.

The stall torque is the maximum torque that the motor can exert, when its rotational speed is zero.

The no-load speed is the maximum rotational speed of the motor axle when no load is attached to it, i.e. when the torque is zero.

It is known that the torque τ and rotational speed ω of the motor axle are related linearly by the equation

$$\tau = -k\omega + \tau_S$$

where k is a constant and τ_S is the stall torque.

Design an experiment to determine the stall torque and no-load speed of a low-power d.c. motor operating on a fixed supply voltage. You are provided with some masses for the experiment. You may also use any of the other equipment usually found in a physics laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the torque exerted by the motor axle and its angular speed are determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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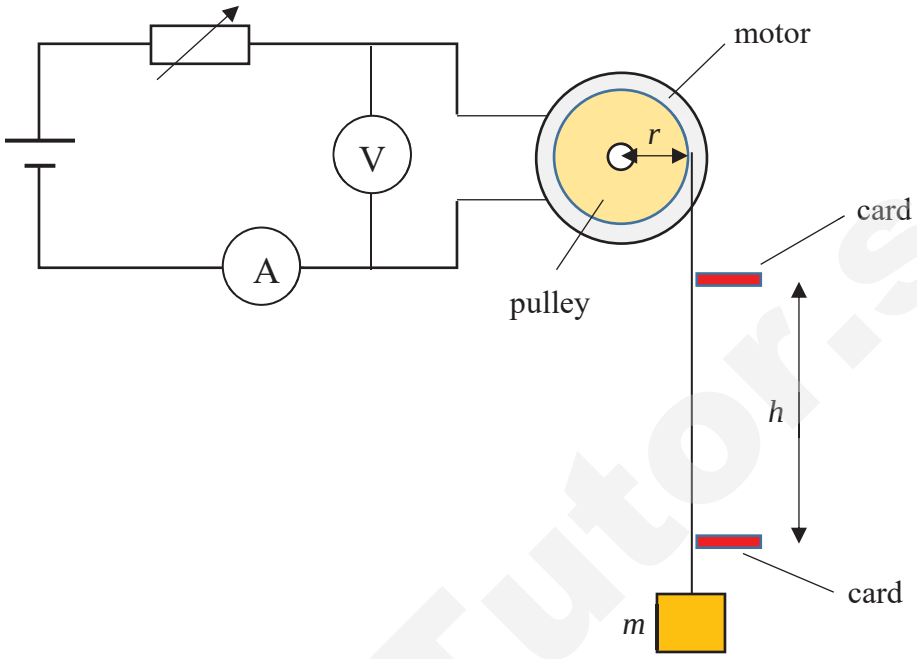
Suggested solution:

Diagram of apparatus:

Apparatus:



(a) Identification and control of variables:

The torque τ applied to the motor axle is varied, and the resulting angular speed ω is measured.

The voltage applied across the motor is kept constant, as a different voltage will give different values of the motor characteristics.

(b) Equipment:

Refer to equipment in the diagram.

(c) Procedure:

1. Use a retort stand to clamp the motor so that its shaft is horizontal.
2. Attach a pulley to the shaft of the motor. Wind a thin but strong string around the pulley groove and, using a metre rule, determine the circumference, and use it to determine the radius r of the pulley via "circumference = $2\pi r$.
3. Attach a string to the pulley.
4. Measure the mass m of the load using an electronic balance.
5. Attach the load to the lower end of the string.
6. Using another retort stand, mount two cards along the string to serve as the start and end points of the timing.
7. Measure the distance h between the two cards.
8. Turn on the motor so that its lifts the load.

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9. Start the stopwatch as the load passes through the bottom card, and stop it when the load crosses the top card. Record this timing as *t*.
10. Calculate the torque τ and the angular speed ω of the motor using the method explained in section (d) below.
11. Repeat steps 2 to 10, in each case varying the mass *m* of the load. Obtain several sets of values of τ and ω.
12. Plot a graph of τ against ω. This graph would be a straight line graph with a negative gradient ($-k$) and a positive y-intercept (τ_S).
13. The value of k is obtained from the gradient.
14. The stall torque τ_S is equal to the y-intercept.
15. The no-load speed ω_0 is obtained from the x-intercept (where $\tau = 0$) which is calculated using "$\omega_0 = \frac{\tau_S}{k}$".

(d) Determination of torque and angular speed:

- The torque τ exerted by the motor is calculated using "$\tau = mgr$".
- The linear speed of the rim of the pulley is calculated using "$v = \frac{h}{t}$".
- The angular speed ω is calculated using "$\omega = \frac{v}{r}$".

(e) Precautions:

(i) Accuracy:

- The height *h* the load is raised through should be sufficiently large to reduce the percentage uncertainty in the measurement of *t*.
- The measurement of the linear speed *v* should be repeated with a shorter *h* to ensure that it is the same as the previous value. This constancy ensures that the motor has accelerated to a constant speed before the timing is started.

(ii) Safety:

- Wear goggles as the rope might snap during the experiment.
- Ensure that the load is light enough so that the motor is able to move it, as a lot of heat will be generated and damage the motor if it is not able to turn while a current is supplied to it.

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Marking Scheme:

Item	**Marking requirement**	**Marks allocated**
Diagram / Apparatus A1	• Diagram to contain all essential details. • Suitable apparatus to be explained using either the diagram *or in writing*. Instruments for any measurement to be mentioned. • Missing or wrong apparatus used or lack of clarity will be penalised.	1
Control of variables B1	• Main variables (torque, angular speed) identified. • Quantity to be kept constant identified (e.g., voltage across motor) <u>with justification provided</u>.	1
Method C1 C2	• Workable method described. Missing essential details to be penalised. • Varying load to vary torque	2
C3	• Torque, $\tau = mgr$	1
D1 D2	• Angular speed, $\omega = \frac{v}{r}$ • $v = \frac{h}{t}$.	2
Graphs E1	• Graphs to be plotted are stated. (τ vs. ω)	1
Deducing results F1	• Identifying stall torque as y-intercept ($\omega = 0$),	1
F2	• Identifying the no-load speed as x-intercept ($\tau = 0$).	1
Precaution (accuracy) G1	Any valid precaution accepted.	1
Precaution (safety) G2	Any valid precaution accepted.	1

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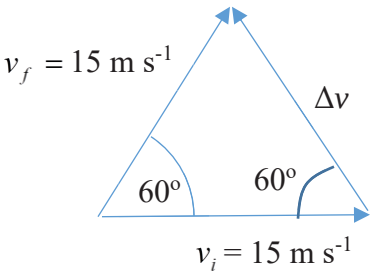
VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2017 PHYSICS PRELIM EXAMS 9749 P1

1. Change in velocity

$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$ or $\vec{v}_f = \Delta\vec{v} + \vec{v}_i$. Hence



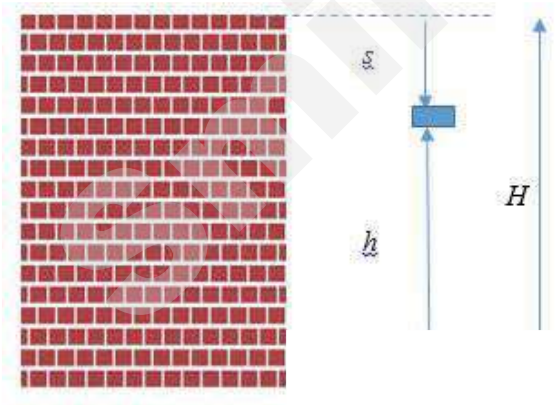
which shows an equilateral triangle, and Δv is 15 m s^{-1} , 60° north of west

Ans: C

2. B is precise because the values fall close to one another, but it is not accurate because the average value is far from x_o.

Ans: B

3.



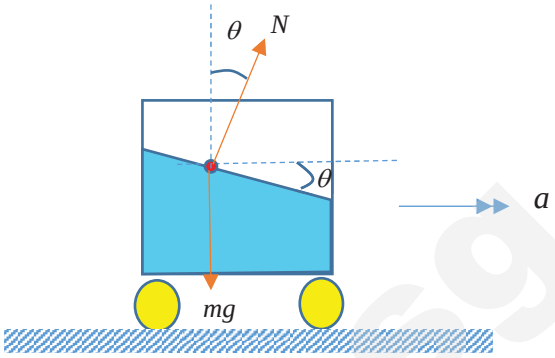
Using "$s = ut + \frac{1}{2}at^2$", we have

$$H - h = \frac{1}{2}gt^2 \text{ or } h = H - \frac{1}{2}gt^2$$

h decreases as t increases, and gradient increases as t increases.

Ans: D

4.



Forces acting on a molecule of mass m on the surface of the water are the weight mg and the normal reaction N.

For vertical equilibrium, $N\cos\theta = mg$…(1)

For horizontal acceleration to the right,

$N\sin\theta = ma$….(2)

$\frac{(2)}{(1)}$ gives $\tan\theta = \frac{a}{g}$

Ans: A

5. Stored energy = ½ $k e^2$
= ½ (500) $(0.020)^2$ = 0.100 J

Ans: A

6. Upthrust on an object in a liquid is due to the pressure difference between the upper and lower parts of the object in the liquid.

Ans: D

7. When kicked at 60°, the soccer ball will still have a velocity at its highest point, hence D is not the answer. At the highest point, the velocity is $v = v_0 \cos 60^0 = \frac{v_0}{2}$.

Hence the final E_k must be

$E_k = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{mv_0^2}{4}\right)$ which is ¼ of the initial E_k. Hence answer is A.

Ans: A

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8. For the satellite to move in a circle about the earth, $\frac{GMm}{r^2} = \frac{mv^2}{r}$ i.e. KE

$$K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$$

Total energy is PE and KE. i.e.

$$E = -\frac{GMm}{r} + \frac{GMm}{2r} = -\frac{GMm}{2r}$$

Ans: A

9. Since the bus is turning to the right and the pendulum is in the bus, the resultant force of the tension in the string and the weight of the bob of the pendulum is to the right.

Ans: C

10. The *x*-*t* graph shows that:

$x = -x_o \cos \omega t$

$\therefore v = +\omega x_o \sin \omega t$

$\therefore a = +\omega^2 x_o \cos \omega t$

Ans: C

11. Period $T = 4$ ms, $f = 1/T = 250$ Hz, $v = f\lambda$,

Estimating the speed of sound in air to be 330 m s^{-1}, $330 = 250\lambda$

$\lambda = 1.32$ m.

Ans: D

12. $I = kA^2 = P/(4\pi r^2)$, or $A\alpha\ 1/r$

Ans: A

13. From the First Law of Thermodynamics, $\Delta U = \Delta Q + \Delta W$
$= 70 - (1.0 \times 10^5)(1.7 \times 10^{-3} - 1.5 \times 10^{-3})$
$= 50$ J

Ans: B

14. **Ans: C**

15. When the current is zero, it is equivalent to saying resistance is infinitely big.
An imaginary line drawn from the origin of the *IV* graph to the line where current increases with p.d. *V* shows the gradient of the imaginary line increasing progressively as *V* increases. But the gradient of the imaginary line is the inverse of resistance. Hence resistance decreases as p.d. *V* increases.

Ans: C

16. The number density of electrons *n* in the wire = $2.0\times10^{21}/(A\times1.0 \times10^{-2}) \text{ m}^{-3}$, where *A* is the cross sectional area of the wire. The current $I = nAve$

$$= \left(\frac{2.0\text{x}10^{21}}{A\text{x}1.0\text{x}10^{-2}}\right) A\left(0.050\text{x}10^{-2}\right)\left(1.6\text{x}10^{-19}\right)$$

$= 16$ A

Ans: B

17. At balance point,

e.m.f. of thermocouple = p.d. across XJ

$$= \frac{R_{XJ}}{R_{XY} + 3000} \times E$$

$$= \frac{\frac{80.1}{100} \times 2.00}{2.00 + 3000} \times 3.0$$

$= 0.00160$ V $= 1.60$ mV

Ans: B

18. Both Q_1 and Q_2 will exert a force of the same magnitude on Q_3 towards themselves. Resolving these two forces horizontally and vertically, the two horizontal force components will cancel each other out. The vertically downward force components will add up to give a net force towards the bottom of the page.

Ans: B

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19. The magnetic force acting on the conductor is zero because the magnetic field due to the current in the solenoid is either parallel or anti-parallel to the current in the linear conductor.

Ans: A

20. No induced current can flow in the broken ring with a gap. Hence Lenz's Law does not operate and the ring remains stationary.

Ans: C

21. As $P = I_{rms}{}^2 R = \frac{I_0{}^2 R}{2}$

Frequency plays no part in affecting the mean rate of production of heat in the pure resistor.

Ans: D

22. A fuse breaks when the power through it exceeds a certain value. Since its resistance is assumed constant, the only factor that needs to be considered is the current. An a.c. supply breaks this fuse at 13 A r.m.s, and hence a d.c. of 13 A will break it too. *Recall the definition of r.m.s current.*

Ans: B

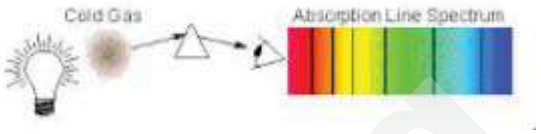
23. If the decelerating p.d. is greater than the stopping potential, not even the electron with the largest kinetic energy can reach the collector.

Ans: D

24. When electrode E is positive, electrons are accelerated from F to E. As long as the frequency of light is fixed and light intensity is constant, the photocurrent will be constant. When E is negative, the photocurrent decreases finally to zero when stopping potential is attained. There is no photoelectric emission from E, implying the work function of E is greater than for F.

Ans: B

25.



This is the arrangement for the production of an absorption spectrum.

Ans: C

26. From the Uncertainty Principle,

$\Delta p \Delta x \geq \frac{h}{4\pi}$

Thus $\Delta p \geq \frac{h}{4\pi\Delta x}$

Given $\frac{\Delta p}{p} = \frac{1}{100} \therefore p = 100\Delta p$

Hence $p_{\min} = 100\frac{h}{4\pi\Delta x}$

$KE_{min} = \frac{p_{min}^2}{2m} = (\frac{25h}{\pi\Delta x})^2 / 2m$

$= [\frac{(25)(6.63\times10^{-34})}{\pi(5.0\times10^{-12})}]^2 / [2(9.11\times10^{-31})]$

$= 6.11 \text{ x } 10^{-13} \text{ J} = \frac{6.11\text{x}10^{-13}}{1.6\text{x}10^{-13}} \text{ MeV}$

= 3.8 MeV

Ans: A

27. Conservation of mass number yields mass no. of X to be zero, while conservation of charge number yields charge no. of X to be –1. Hence X = $^{0}_{-1}e$.

Ans: A

28. Energy released = binding energy of product nuclei – binding energy of reactant nuclei

= $B_{He} - 2B_H = 2.54\times3 - 1.09\times2\times2$

= 3.26 MeV

Ans: C

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29. When the parent nuclei have decreased by half its original number, the daughter nuclei would have increased from zero to half the original parent nuclei. This occurs after a half-life τ.

Ans: C

30. Rate of decay

$A = \lambda N = \frac{\ln 2}{t_{\frac{1}{2}}} N = \frac{\ln 2}{t_{\frac{1}{2}}} (nN_A)$ where n and N_A are number of moles and Avogadro's number respectively.

Hence $A \propto \frac{n}{t_{\frac{1}{2}}}$. The ratio $\frac{200}{6200}$ is the smallest.

Ans: D

******* END ******

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Q1. (a)
The voltmeter or ammeter might have a zero error.

To overcome this error, the meters should be adjusted to remove the zero error before the experiment.

1(b)(i) $R = \frac{V}{I}$ and $R = \frac{\rho L}{A}$, hence

$$\frac{V}{I} = \frac{\rho L}{A} \Rightarrow \rho = \frac{VA}{IL} = \frac{\pi V d^2}{4IL}$$

1(b)(ii)

$$\rho = \frac{\pi V d^2}{4IL} = \frac{1.50 \times \pi \times (0.48 \times 10^{-3})^2}{4 \times 0.82 \times 0.632}$$
$$= 5.23 \times 10^{-7} \Omega \text{ m}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta L}{L} + 2\frac{\Delta d}{d}$$
$$= \frac{0.01}{1.50} + \frac{0.01}{0.82} + \frac{0.1}{63.2} + 2\frac{0.02}{0.48} = 0.1037$$

$$\Delta\rho = 0.1037\rho = 0.1037 \times 5.23 \times 10^{-7}$$
$$= 0.54 \times 10^{-7} \approx 0.5 \times 10^{-7} \Omega$$

Hence,
$\boldsymbol{\rho = (5.2 \pm 0.5) \times 10^{-7} \Omega \text{ m}}$

1(c)
The introduction of a second metal in an alloy distorts the lattice structure of the first metal, and vice versa, making it more difficult for electrons to move through the alloy, resulting in increased electrical resistivity.

Q2(a)(i)
Taking upwards positive,
$v_y = u_y + a_y t$

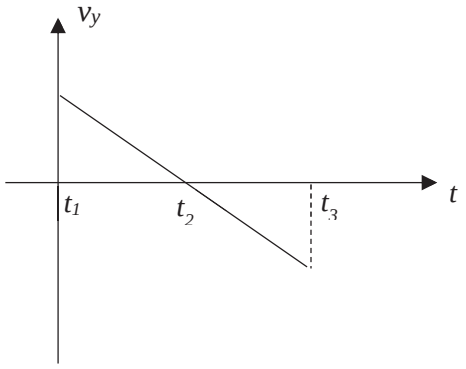
At the highest point,
$0 = u \sin 30^0 + (-9.81)(3.0 / 2)$
$\boldsymbol{u = 29.4 \text{ m s}^{-1}}$

2(a)(ii)
$s_y = ½ (u_y + v_y) t$

$= ½ (29.4 \sin 30^0 + 0)(3.0 / 2)$
$= 11.0$ m

Maximum height above the ground
$= 11.0 + 1.5 =$ **12.5 m**

2(b)



2(c)
With air resistance, the deceleration of the ball as it rises is greater compared with the situation where air resistance is negligible. OR Work has to be done by ball to overcome air resistance as it rises above the ground.

Hence the maximum height reached will be smaller.

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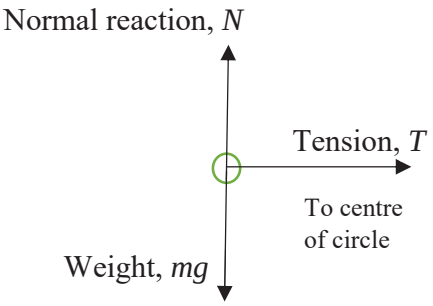
Q3(a)



Side view of forces acting on the mass.

3(b)
Resultant force = tension = kx

= (40) (0.70-0.50) = **8.0 N**

3(c)
Centripetal force = tension

$$\frac{mv^2}{r} = kx$$

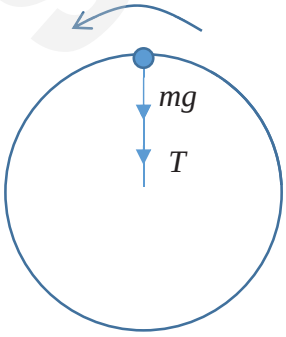
$$v = \sqrt{\frac{(8.0)(0.70)}{0.050}} = \mathbf{10.6\ m\ s^{-1}}$$

3(d)

$$v = \frac{2\pi r}{T}$$

$$T = \frac{2\pi(0.70)}{10.6} = \mathbf{0.42\ s}$$

3(e)



Consider the object moving in a circular path in a vertical plane. Fr circular motion of the object,

$T + mg = \frac{mv^2}{r}$ where T and m are the tension in the string and the mass of the object respectively.

To just become slack, the tension in the string just drops to zero. Hence $\boldsymbol{v_{min} = \sqrt{rg}}$

Q4(a)
Lamps do not produce coherent light as the photons are emitted from different points on each lamp.

The light waves meeting at a point have random and rapidly changing phases resulting in only a bright patch.

4(b)(i)
The path difference between the two waves from the aircraft to aerials P and Q will change with time as the aircraft flies overhead.

The waves may be received by P and Q in phase (maximum signal) or out of phase (minimum signal).

4(b)(ii)
Minimum distance travelled by aircraft corresponds to the fringe separation y between two successive maxima (Analogy: Young's double-slit experiment)

$$\boldsymbol{y = \frac{\lambda h}{D}}$$

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4(b)(iii)
Thick clouds

Tall buildings nearby.

Q5(a)
Induced e.m.f. = *Bxv*

= (0.25)(0.50)(2.0) = **0.25 V**

5(b)
Induced current =
Induced emf/Resistance
= 0.25/0.50 = **0.50 A**

in a direction clockwise around the loop.

5(c)
Arm PQ will experience a magnetic force as a result of the induced current. If it is not fixed, this will cause the loop to move to the left by FLHR.

Arm PQ will then have an induced e.m.f. which will oppose the e.m.f. in RS.

This will result in an induced current smaller than in (b).

5(d)(i)
The magnetic field due to the induced current in QP will be significant due to the large current. This would affect the magnitude of the original magnetic field on RS and hence the induced emf.

5(b)(ii)
Larger than in part (a). The induced magnetic field of QP in the region of RS points into the paper, and hence the resultant magnetic field acting on RS is now stronger.

Hence the induced e.m.f. will be larger.

Q6(a) (i)
Energetic incoming electrons knock out the electrons in the inner shells of target atoms, leaving vacancies behind.

Electrons from the outer shells fall in to fill up the vacancies and X-ray photons are emitted.

The energy of an x-ray photon has a characteristic wavelength determined by the energy difference between the two energy levels involved in the downward transition.

6(a)(ii)
When an incoming electron loses practically all its kinetic energy in a single encounter with a target nucleus, the photon emitted has an associated wavelength corresponding to the cut-off wavelength.

6(b)
Energy of incoming electron = energy of x-ray photon

$$qV = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{qV} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(1.6\times10^{-19})(75000)}$$

$$= \mathbf{1.66\times10^{-11}\,m}$$

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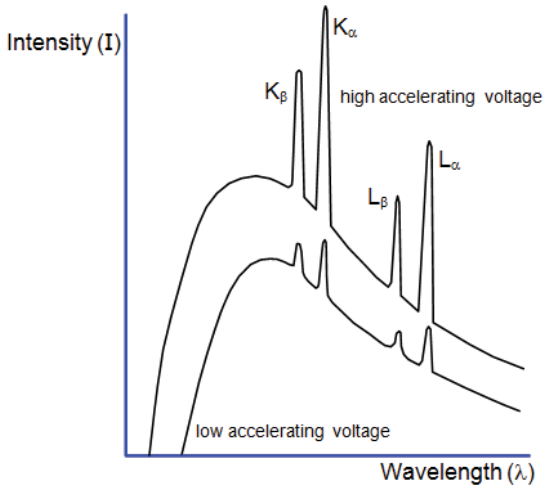
6(c)



Q7(a)
α-particle and proton.

7(b) $\Delta m = m_O + m_H - m_N - m_{He}$
$\Delta m = 16.9947u + 1.0073u - 13.9993u - 4.0015u$
$= 1.2\times10^{-3}\times1.66\times10^{-27}$
$= \mathbf{1.99\times10^{-30}\ kg}$

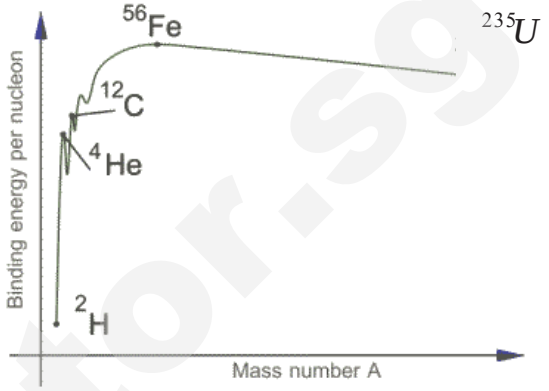
7(c)
$(m_O + m_H - m_N - m_{He})c^2 = K_\alpha - K_O - K_H$

Minimum $K_\alpha = (m_O + m_H - m_N - m_{He})c^2$
$(\Delta m)c^2 = 1.99\times10^{-30}c^2 = \mathbf{1.79\times10^{-13}\ J}$

7(d) Mass defect of helium nucleus = mass of 2 protons and 2 neutrons – mass of helium nucleus
Binding energy = mass defect x c^2

= [2(1.0073)+2(1.0087)-4.0015] x$1.66\text{x}10^{-27}$x$(3.0\text{x}10^8)^2$
= 4.5567 x 10^{-12} J
$= \dfrac{4.5567\text{x}10^{-12}}{1.6\text{x}10^{-13}} \approx 28.479$ Mev
$= \dfrac{28.479}{4} \approx \mathbf{7.12\ MeV\ per\ nucleon.}$

7(e)(i)



7(e)(ii) The fission of a heavy nucleus such as ^{235}U will lead to two daughter fragments, each with a mass number smaller than that of the parent nucleus.
The binding energy per nucleon of the daughter fragments will be higher up the binding energy per nucleon graph, corresponding to increased stability.

Q8(a)
USA car: 30 mpg = $\dfrac{30}{0.621}$ km per 3.79 litres.

Hence 100 km corresponds to
$\dfrac{3.79}{\left(\dfrac{30}{0.621}\right)}$ x100 =7.85 litres of fuel.

European model: 7.80 *l*/100 km. The European model is more fuel-efficient by **0.05 litre/100 km**.

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8(b)
European car: original fuel efficiency is 7.80 litres for every 100 km. Hence distance covered per litre is $\frac{100}{7.80}$ km/*l*. =12.8 km/*l*

Percentage increase in fuel efficiency is $\frac{15.38-12.8}{12.8}$x100

≈ 20% improvement.

8(c)(i)
Total distance travelled = area under *v*-*t* graph over 2 hr
s = 60x0.5 +120x0.5 +80x0.5+100x0.5
=**180 km.**

8(c)(ii)
The gradient of the *v*-*t* graph at 0.5 hr, 1.0 hr and 1.5 hr is infinite.

This is unrealistic because a car cannot achieve infinite acceleration.

8(c)(iii)
The total work done against air drag is the product of force and distance travelled for each time interval over the first hour.

W = 245x 30 x 10^3+540 x 60x10^3

≈ 3.98 x 10^7 J

8(c)(iv)
Let work done to overcome air drag be *W*.
Then efficiency $\eta = \frac{W}{EV}$ where *E* = 35 MJ per litre, and *V* is the volume of fuel required.

$V = \frac{W}{\eta E}$. The total volume of fuel must be calculated for each velocity of the car over the first one hour since efficiency η is velocity-dependent.

$$V = \frac{1}{35\text{x}10^6}\left(\frac{245\text{x}30\text{x}10^3}{0.076}+\frac{540\text{x}60\text{x}10^3}{0.152}\right)$$

≈ 8.9 litre

8(c)(v)
Fuel used per kilometre for the first half hour is $\frac{245\text{x}30\text{x}10^3}{35\text{x}10^6\,\text{x}0.076}\left(\frac{1}{30}\right) = 9.21\text{x}10^{-2}$ litre

Fuel used per kilometre for the second half of the first hour is $\frac{540\text{x}60\text{x}10^3}{35\text{x}10^6\,\text{x}0.152}\left(\frac{1}{60}\right)$
≈ 10.2 x 10^{-2} litre

Hence fuel is used more efficiently in the first half of the first hour.

********* END ********

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Section A

Q1(a). When the sand impacts on the conveyor belt, it has zero initial horizontal velocity. Friction drags the sand particles along the surface of the conveyor belt, causing the sand to attain a final horizontal velocity of $v = 0.75$ m s^{-1}. Hence

From N2L, $f = ma = \dfrac{m(v-0)}{t}$

$= (5.00)(0.75) =$ **3.75 N**

1(b) The external force is opposed by the force exerted on the conveyor belt by the sand particles. By Newton's 3rd Law, this force is numerically 3.75 N.
Hence F_{ext} = 3.75 N

1(c) Power due to F_{ext} is
$P = F_{ext}\, v$
$= 3.75\ (0.75) \approx$ **2.81 J s^{-1}**

1(d) Rate of change of kinetic energy is

$$\frac{dK}{dt} = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = \frac{1}{2}v^2\left(\frac{dm}{dt}\right)$$

$$= \frac{1}{2}(0.75^2)(5.00) \approx \textbf{1.41 J s}^{-1}$$

The rate of change of kinetic energy of the sand is half of the power due to F_{ext}.

Half of the work done by the external force is due to work done to overcome friction between the sand and the conveyor belt.

Q2(a) $KE = \dfrac{1}{2}mv^2 = 0.5 \times 1300 \times (16.7)^2$
$= \mathbf{1.81 \times 10^5\ J}$

2(b)(i) Let total external forces opposing motion of car be R. Then driving force $F = R$ since velocity is constant.
$P = Fv = (240 + 0.98v^2) \times v$

$R = 240 + 0.98v^2 = 240 + 0.98(16.7)^2$
$=$ **513 N**

2(b)(ii) Work done = Force x Distance
= R x velocity x time

= 513 x 16.7 x (3x 60) = $\mathbf{1.54 \times 10^6\ J}$

2(c) Advantage: Electric cars are non-polluting unlike hybrid cars which emit fumes from consumption of petrol.

Disadvantage: Because electric vehicles use electric power alone, there's no backup engine when the batteries run out of energy.

Q3(a) The earth effectively orbits about the centre of the sun because the sun has a much bigger mass compared to the earth.

3(b)

$$\omega = \frac{2\pi}{T}$$

$$\approx \frac{2\pi}{(365)(24)(60)(60)} \approx \textbf{2.0 x 10}^{-7}\ \textbf{rad s}^{-1}$$

3(c) For circular motion of the earth about the sun, we have

$$\frac{GM_1M_2}{R^2} = M_2R\omega^2$$

$$\omega^2 = \frac{GM_1}{R^3} \text{ or } \omega \propto R^{-\frac{3}{2}}$$

The constant of proportionality is $\sqrt{GM_1}$

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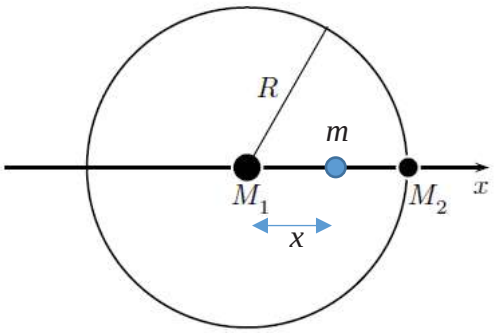
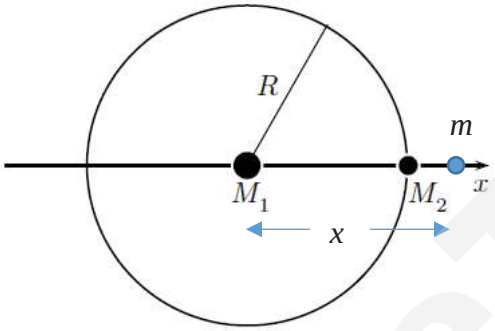
3(d)(i)



First possible equation:

$$\frac{GM_1m}{x^2} - \frac{GM_2m}{(R-x)^2} = mx\omega^2$$



Second possible equation:

$$\frac{GM_1m}{x^2} + \frac{GM_2m}{(x-R)^2} = mx\omega^2$$

3(d)(ii) The assumption is that there are no massive celestial objects in the vicinity of mass *m*.

Q4(a)(i) Initial momentum, $p_i = mu$
(taking right as positive direction)
Final momentum, $p_f = -mu$
Change in momentum of a molecule = $\mathbf{-2mu}$

4(a)(ii) Time taken by one molecule between collisions with wall A, $\boldsymbol{t = \frac{2l}{u}}$

4(a)(iii) Rate of change of momentum for all molecules colliding with wall A

$$= N\left|\frac{-2mu}{\left(\frac{2l}{u}\right)}\right|$$

$$= \frac{\boldsymbol{Nmu^2}}{\boldsymbol{l}}$$

By N2L, force = rate of change of momentum

Or $\boldsymbol{F = \frac{Nmu^2}{l}}$ (force exerted on wall by N3L)

4(b) Pressure = Force / Area

Pressure, $p = \frac{Nmu^2}{l^3}$

$\boldsymbol{P = \frac{Mu^2}{V}}$ (shown)

4(c) The expression in (b) assumes that all the molecules move in only one dimension when in fact, they move in three dimensions.

The expression also assumes that all the molecules move with only one speed when they actually move with a range of speeds.

Q5(a) p.d. across voltmeter is

$$\boldsymbol{V = \frac{R_v}{R_v + r}E}$$

5(b) If the voltmeter reading is within 0.1 % of the e.m.f.,

$$\frac{E-V}{E} \leq 0.001$$

$1 - \frac{V}{E} \leq 0.001$ or $1 - \frac{R_v}{R_v+r} \leq 0.001$
$\therefore \frac{r}{R_v + r} \leq 0.001$
$\therefore 1000r \leq R_v + r$
$\therefore R_v \geq 999r = 999 \times 0.10 = 99.9$
$\therefore \boldsymbol{R_{v(min)} = 99.9\ \Omega}$

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5(c)(i) The voltmeter and the resistor R form a parallel load resistance that the cell is connected across.The equivalent resistance of the voltmeter and resistor R in parallel is:

$$R_{\parallel} = \frac{R_v \times R}{R_v + R}$$

By the voltage divider rule, the voltmeter reading is

$$V = \frac{R_{\parallel}}{R_{\parallel} + r} \times E$$

$$V = \frac{\frac{R_v \times R}{R_v + R}}{\frac{R_v \times R}{R_v + R} + r} \times E$$

$$\boldsymbol{V = \frac{R_v R}{R_v R + r R_v + r R} \times E}$$

5(c)(ii)

$$V = \frac{\boldsymbol{R}}{\boldsymbol{R + r + \frac{rR}{R_v}}} \times \boldsymbol{E}$$

If $R_v = 99.9\ \Omega$, $r = 0.10\ \Omega$ and $R = 0.90\ \Omega$,

$$V = \frac{0.90}{0.90 + 0.10 + \frac{0.10 \times 0.90}{99.9}} \times 2.0$$

$\therefore V =$ **1.80 V**

Q6 Let $N = 200$, $r_1 = 12.0$ cm,
$D = 1.0 \times 10^4$ kg m^{-3},
$\rho = 2.0 \times 10^{-8}\ \Omega$ m, $r_2 = 0.457 \times 10^{-3}$ m

6(a) Resistance of the coil is

$$R = \rho \frac{L}{A} = \rho \frac{2\pi r_1}{\pi r_2^{\,2}} N$$

$$R = \frac{(2.0\text{x}10^{-8})(2)(12.0\text{x}10^{-2})(200)}{(0.457\text{x}10^{-3})^2}$$

$\approx$ **4.60** Ω

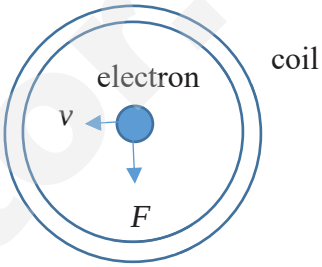
6(b) Magnetic field at the centre of the coil is $B = \frac{\mu_0 NI}{2r_1}$

Applying Ohm's Law,

$$B = \frac{\mu_o NV}{2r_1 R} \text{ or } V = \frac{2Br_1 R}{\mu_0 N}$$

$$= \frac{2(5.0\text{x}10^{-3})(12.0\text{x}10^{-2})(4.60)}{(4\pi\ \text{x}10^{-7})(200)} \approx \mathbf{22.0\ V}$$

6(c)



The force acting on the electron is

$$F = Bev$$
$$= (5.0\text{x}10^{-3})(1.6\text{x}10^{-19})(4.0\text{x}10^{5})$$
$$= \mathbf{3.2\ x10^{-16}\ N}$$

By Fleming's LHR, the magnetic field at the centre of the coil is directed **out of the plane of the paper.**

Q7(a)(i) $^{23}_{12}Mg \rightarrow ^{23}_{11}Na + ^{0}_{1}e + \upsilon$

Products of the decay: Na-23 nucleus, positron and neutrino.

7(a)(ii) From $A = \lambda N = \left(\frac{\ln 2}{t_{\frac{1}{2}}}\right)\left(\frac{M}{M_m} N_A\right)$

Initial rate of decay

$$A = \left(\frac{\ln 2}{11.3}\right)\left[\left(\frac{1}{23}\right)(6.02 \times 10^{23})\right]$$
$$= \mathbf{1.61 \times 10^{21}\ Bq}$$

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7(b)(i) Gamma radiation is uncharged and is thus unaffected by an electric field.

7(b)(ii) α and β particles are charged particles and they will be deflected when travelling perpendicular to the electric field.

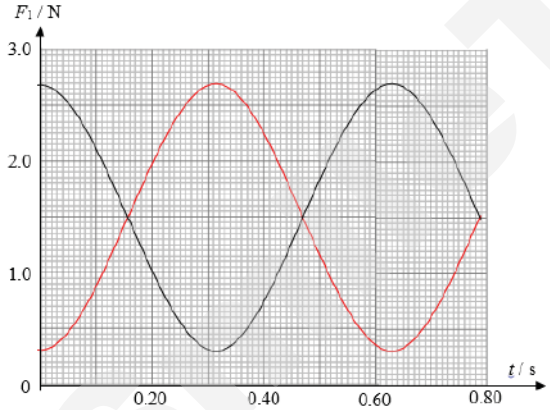
The particles curve in parabolic paths.

7(b)(iii) Tracks are not drawn to scale. The β particles should curve very much more than for the α particles because they are so much lighter.

The charged particles should be travelling straight after exiting the electric field and not continue in a curved path.

Section B

8(a)



(b) T = **0.63 s**.

(c) $\omega^2 = \frac{k_{eff}}{m}$

$$\therefore \left(\frac{2\pi}{T}\right)^2 = \frac{k_{eff}}{m}$$

$$\therefore \left(\frac{2\pi}{0.63}\right)^2 = \frac{k_{eff}}{0.200}$$

$\therefore$ k_{eff} = **20.0 N m^{-1}**.

(d) When the mass is displaced by x to the right,

Net force = $T_2 - T_1$

$$\therefore ma = k(e - x) - k(e + x)$$

$$\therefore ma = -2kx$$

$$\therefore a = -\frac{2k}{m}x \propto -x$$

$\therefore$ the motion is simple harmonic.

(e) Net force = $F = -2kx$

$\therefore$ $k_{eff} = 2k$

$\therefore$ force constant for each spring = k = 20.0/2 = **10.0 N m^{-1}**.

(f) From the graph, it is seen that

When $x = x_0$, F_1 = 2.70 N.

$$\therefore k(e + x_0) = 2.70$$

$$\therefore 10.0(0.150 + x_0) = 2.70$$

$\therefore$ amplitude = x_0 = **0.120 m**.

(g) Maximum speed = $v_0 = \omega x_0$

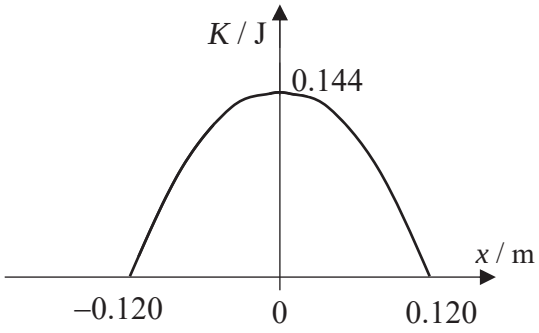
$$\therefore v_0 = \frac{2\pi}{T} \times x_0$$

$$\therefore v_0 = \frac{2\pi}{0.63} \times 0.120 = \mathbf{1.20\ m\ s^{-1}}$$

(h) $K_0 = \frac{1}{2}mv_0^2 = \frac{1}{2} \times 0.200 \times 1.20^2$

$$= \mathbf{0.144\ J}$$

(i)



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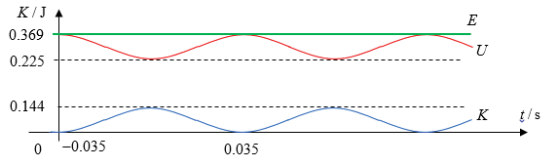
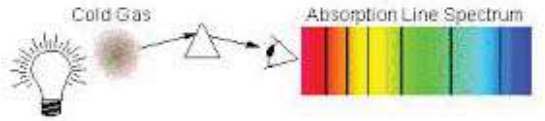
(ii) The PE is minimum at the equilibrium position.

$$\text{Minimum PE} = \frac{1}{2}ke^2 + \frac{1}{2}ke^2 = ke^2$$
$$= 10.0 \times 0.150^2$$
$$= \mathbf{0.225\ J}$$



Q9(a)(i)

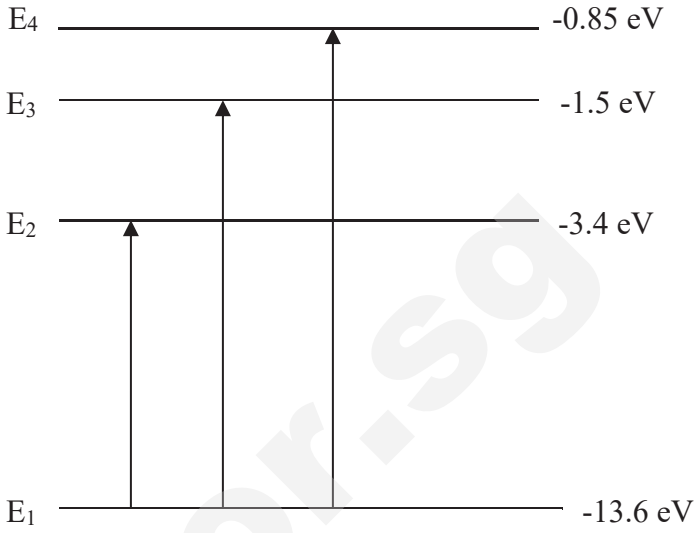


White light is sent through a cool gas. The gas atoms absorb certain characteristic frequencies from the white light and get excited to higher energy states in the process.

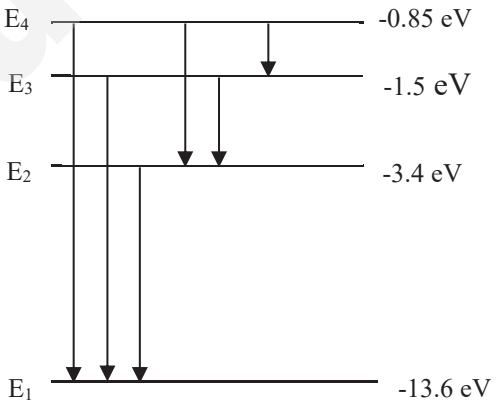
As the atoms de-excite, they re-emit the light in all possible directions.

These frequencies will therefore be practically missing on the spectral photograph. They correspond to dark lines against a coloured background.

9(a)(ii)



9(a)(iii)



9(a)(iv) **13.6 eV**

9(a)(v) The hydrogen atom can get ionised with the excess kinetic energy of the **bombarding electron** shared between the **bombarding electron** and the electron that **is ejected from the atom** due to an effective **collision.**

The hydrogen atom can also get excited to any other excited state with the bombarding electron carrying away the excess kinetic energy due to a not-so-effective collision.

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9(b)(i)1. In the photoelectric effect, bombarding photons produce electrons, while in X-ray production, bombarding electrons produce photons of X-rays.

9(b)(ii)1. **0.035 nm**

9(b)(ii)2. The wavelength in 9(b)(ii)1 is due to a photon travelling at the speed of light, while the de Broglie wavelength of the bombarding electron is associated with wave nature of the moving electron.

9(c)(i) If the accelerating p.d. is increased, the bombarding electrons will have sufficient kinetic energy to interact with more target nuclei, causing the release of more photons.

Hence the intensity of x-radiation will increase.

9(c)(ii) The wavelengths of the characteristic x-ray spectrum are unique to the nature of the target metal.

Since the target remains the same during the increase in p.d, , the wavelengths of the characteristic spectrum will not change.

9(d)(i) Increasing the tube current increases the number of electrons per unit time striking the target metal.

This will lead to more interactions with target atoms, leading to increased intensity in x-radiation.

9(d)(ii) Increasing the exposure time leads to longer time for heating of the filament, leading to greater temperature of the filament in the x-ray tube. The result is more electrons will be produced per second from thermionic emission.

This will lead to more interactions with target atoms, leading to increased intensity in x-radiation.

********* END **********

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Candidate's name …… CTG ……

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/1**
HIGHER 2 **15th September 2017**
1 hour

Paper 1 Multiple Choice

Additional Material:
Optical Mark Sheet

YISHUN JUNIOR COLLEGE YISHUN JUNIOR COLLEGE YISHUN JUNIOR COLLEGE YISHUN JUNIOR COLLEGE

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name and CTG on the Optical Mark Sheet in the spaces provided.
Shade your NRIC in the space provided.

There are **thirty** questions in this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D.**

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

Read the instructions on the Optical Mark Sheet carefully.

INFORMATION FOR CANDIDATES
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o nI$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 The intensity of a beam is defined as the energy delivered per unit area per unit time.

What is the base unit of intensity?

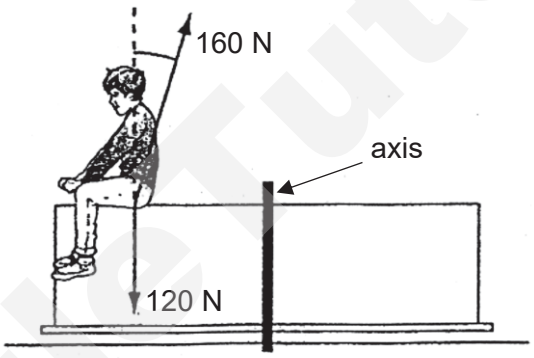
A kg m^2 s^{-3} **B** kg m s^{-3} **C** kg s^{-2} **D** kg s^{-3}

2 Car A and car B were having a race along a straight line towards the finishing line. Car A was moving at a speed of 40 m s^{-1} and car B was moving at a speed of 50 m s^{-1} when car B overtook car A. After 1.0 s of reaction time, car A accelerated to 55 m s^{-1} uniformly in another 1.0 s. Car A then moved at that constant speed.

What is the total time taken for car A to catch up with car B? Assume that car B maintained a constant velocity throughout.

A 1.3 s **B** 2.2 s **C** 4.5 s **D** 17.5 s

3 A child is sitting on a playground turntable and is rotating about its axis with uniform angular velocity.



The resultant force that the turntable exerts on the child is 160 N and the weight of the child is 120 N.

What is the acceleration of the child?

A 0.88 m s^{-2}

B 3.3 m s^{-2}

C 8.7 m s^{-2}

D 84 m s^{-2}

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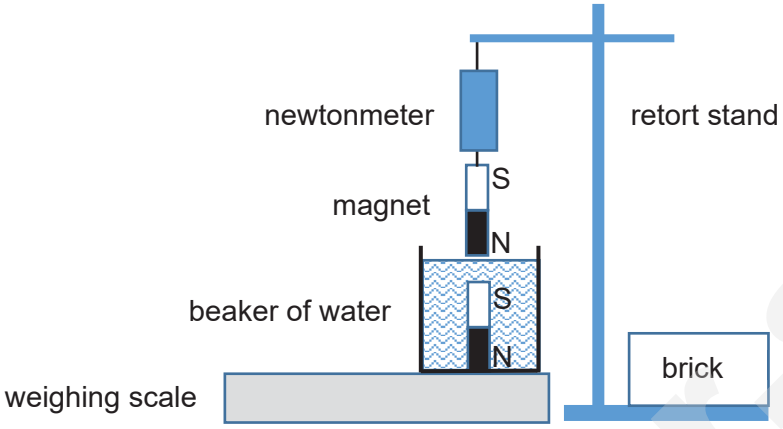
4 A beaker of water of total weight J is placed onto a weighing scale and a magnet of weight Q is added into it. An identical magnet is suspended just above the surface of the water and is supported by a newtonmeter hanging from a retort stand. The newtonmeter registers a reading of S.



Which of the following shows the reading on the weighing scale?

A 2Q + J – S

B Q + J + S

C Q + J – S

D J + S

5 An alpha particle and a beta particle move in a straight line towards the east with a constant speed of 7.2×10^7 m s^{-1} and 3.6×10^4 m s^{-1} respectively. They move independently of each other and are under the influence of electric, magnetic as well as gravitational fields. They both moved a distance of 1.0 m.

Which of the following statements is true?

A There is no net work done on either of them.

B There is more net work done on the alpha particle than the beta particle.

C There is more net work done on the beta particle than the alpha particle.

D The net work done on the beta particle is positive while the net work done on the alpha particle is negative.

6 A lorry of mass 2000 kg has an engine which can deliver a maximum power of 50.0 kW.

What is the minimum time in which the lorry can be accelerated from rest to a speed of 100 km h^{-1} along a flat road? Ignore all resistive forces acting on the lorry.

A 11.3 s **B** 15.4 s **C** 30.9 s **D** 200 s

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7 Mass m moves in a horizontal circle of radius r at constant angular speed ω.

Which pair of values correctly gives the work done by the centripetal force and the change in linear momentum of the body in the duration of π/ω ?

	work done	change in linear momentum
A	$2mr^2\omega^2$	$2mr\omega$
B	$\pi mr^2\omega^2$	$2mr\omega$
C	0	0
D	0	$2mr\omega$

8 An object is tied to a string and is swung around in horizontal circular motion of radius r at increasing speeds. The string breaks when the speed of the object is v.



The object is now tied using two strings instead and is swung around with the same radius.

What is the speed of the object when the string breaks?

A 0.707 v **B** 1.41 v **C** 2.00 v **D** 4.00 v

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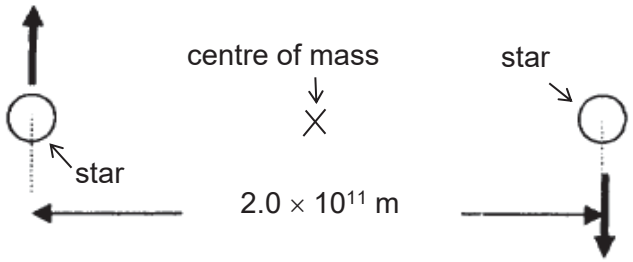
9 A binary star system consists of two stars, each of mass 4.0×10^{30} kg, separated by a distance of 2.0×10^{11} m. The stars rotate about the centre of mass of the system.



What is the period of rotation of each star?

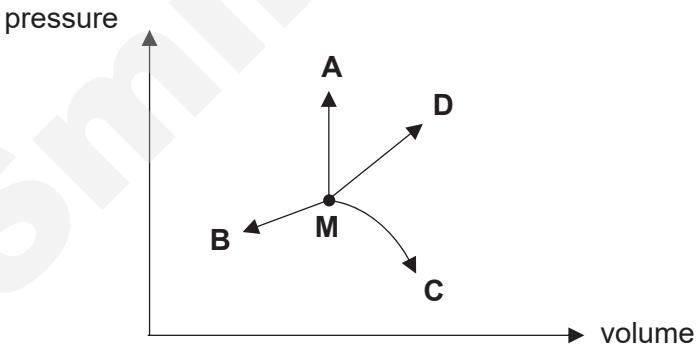
A 1.2×10^{7} s **B** 1.7×10^{7} s **C** 2.4×10^{7} s **D** 3.4×10^{7} s

10 The radius of planet X is R and its density is ρ. Planet Y has a radius of $5R$ and a density of $\frac{1}{4}\rho$. The escape speed of an oxygen molecule at planet X's surface is v.

The escape speed of the oxygen molecule at the surface of planet Y is

A 0.22 v **B** 0.40 v **C** 2.5 v **D** 4.5 v

11 A gas, which is initially at state M can be made to undergo four different thermal processes, namely A, B, C and D.



Which one of the processes results in the greatest work done on the gas?

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12 How would the internal energy of an ideal gas change if it undergoes the following processes separately?

Process 1: compressed at constant pressure

Process 2: heated at decreasing volume

	Process 1	Process 2
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

13 A gas at a temperature of 30 °C is heated such that the root-mean-square speed of its molecules increases by 5%.

What is the new temperature of the gas?

A 32 °C **B** 33 °C **C** 45 °C **D** 61 °C

14 The frequency of a body moving with simple harmonic motion is doubled.

If the amplitude remains the same, which of the following quantities is also doubled?

A time period

B total energy

C maximum velocity

D maximum acceleration

15 When a particle performs simple harmonic motion, the velocity leads the displacement by a phase angle of

A $\frac{\pi}{2}$ rad **B** $\frac{\pi}{4}$ rad **C** π rad **D** zero

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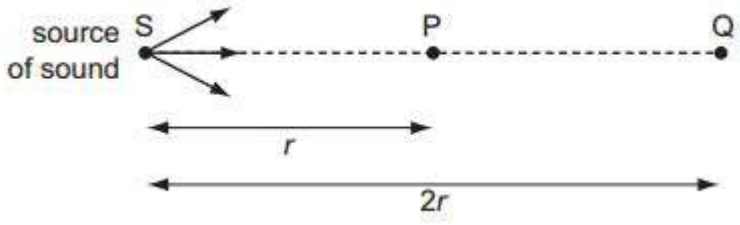
16 A point source S is emitting sound waves in all directions.



Air molecules at P, a distance *r* from S, oscillate with amplitude 8.0 μm. Point Q is situated a distance 2*r* from S.

What is the amplitude of oscillation of air molecules at Q?

A 1.4 μm **B** 2.0 μm **C** 2.8 μm **D** 4.0 μm

17 In a double-slit experiment, the slit separation is 2.0 mm, and two wavelengths of light, 750 nm and 900 nm, illuminate the slits. A screen is placed 2.0 m from the slits.

What is the minimum distance from the central maximum on the screen that a maximum from one pattern coincide with the maximum from the other?

A 1.5 mm **B** 3.0 mm **C** 4.5 mm **D** 6.0 mm

18 Two coherent wave-trains of monochromatic light arrives at a point on a screen.

Which of the following statements must be true?

A They are in phase.

B They have a constant phase difference.

C They interfere constructively.

D They interfere destructively.

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19 Diagram 1 shows a ripple tank experiment in which plane waves are diffracted through a narrow slit in a metal sheet.

Diagram 2 shows the same tank with a slit of greater width.

In each case, the pattern of waves incident on the slit and the emergent pattern are shown.

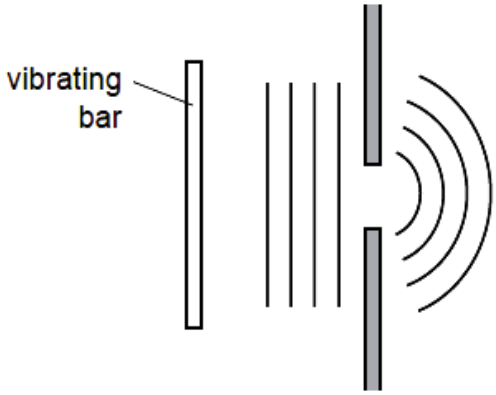

diagram 1

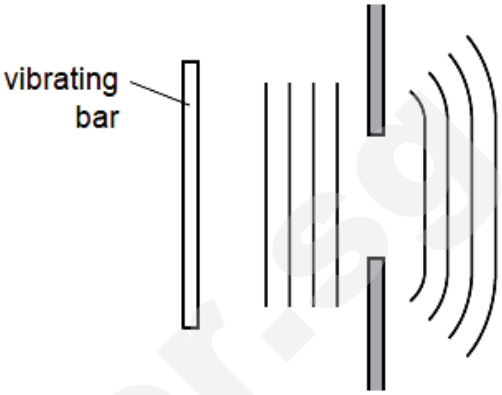

diagram 2

Which of the following changes would cause the waves in diagram 2 to diffract more and produce an emergent pattern closer to that shown in diagram 1?

A Reduce the length of the vibrating bar

B Reduce the amplitude of vibration of the bar

C Increase the frequency of vibration of the bar

D Increase the speed of the waves by making the water in the tank deeper

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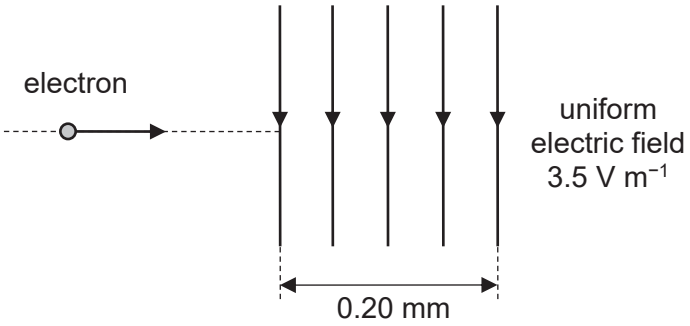
20 An electron travels horizontally at a speed of 5500 m s^{-1} and enters a uniform vertical electric field of strength 3.5 V m^{-1}, which is directed downwards and acts over a horizontal distance of 0.20 mm.



What is the speed of the electron when it exits the electric field?

A 5.50×10^3 m s^{-1}

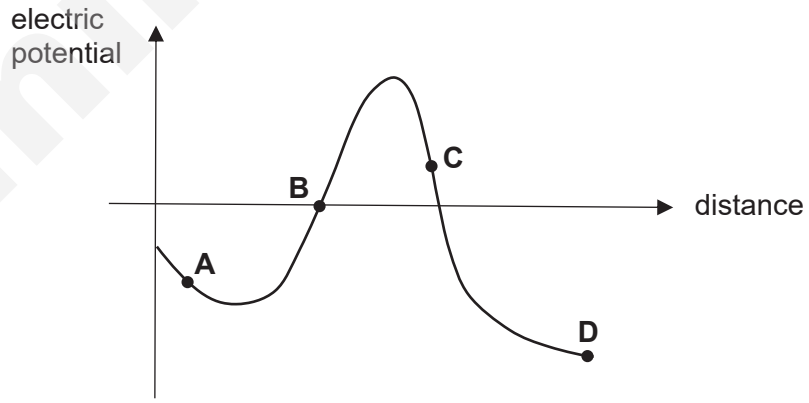
B 2.24×10^4 m s^{-1}

C 2.31×10^4 m s^{-1}

D 2.79×10^4 m s^{-1}

21 The diagram below shows the variation of electric potential with distance along a straight line in a region of electric field.

Which of the following positions represents a point with maximum electric field strength?



22 Aluminium and copper cylindrical rods are designed to have the same length and the same resistance. The resistivity of copper is half that of aluminium and its density is three times that of aluminium.

What is the ratio of the mass of the copper rod to the mass of aluminium rod?

A 0.167 **B** 0.667 **C** 1.50 **D** 6.00

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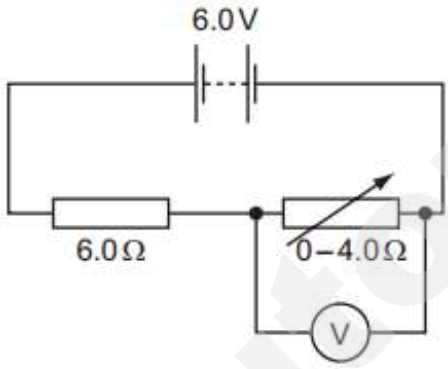
23 A current flows in a wire of circular cross-section of radius *r* with the free electrons travelling at drift velocity *v*.

What is the drift velocity for the same current in a wire of the same material but of half the radius?

A 0.25 *v* **B** 0.5 *v* **C** 2 *v* **D** 4 *v*

24 An ideal 6.0 V e.m.f source is connected in series with a 6.0 Ω resistor and a variable resistor. The resistance of the variable resistor is varied between 0 Ω and 4.0 Ω.



What is the range of the voltmeter reading?

A 0 V to 2.4 V

B 0 V to 3.6 V

C 2.4 V to 6.0 V

D 3.6 V to 6.0 V

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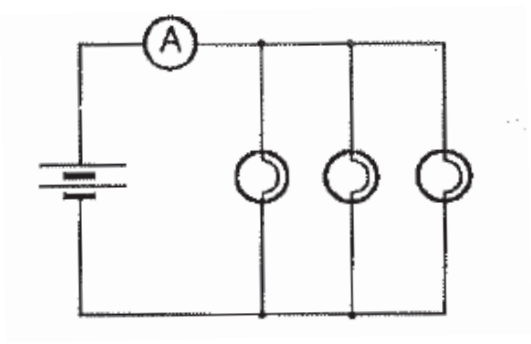
25 Three similar light bulbs are connected to a constant voltage d.c. supply of negligible internal resistance. Each bulb operates at normal brightness and the ideal ammeter register a steady current.



The filament of one of the bulbs breaks.

What happens to the ammeter reading and the brightness of the remaining bulbs?

	ammeter reading	bulb brightness
A	decreases	decreases
B	decreases	remains unchanged
C	increases	remains unchanged
D	increases	increases

26 A straight current-carrying wire lies at right angles to a horizontal magnetic field as shown in diagram A. The field exerts a force of 8.0 mN on the wire.

The wire is now rotated, in its horizontal plane, through 30° and the flux density of the magnetic field is halved, as shown in diagram B.

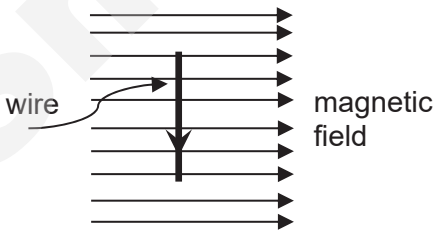


diagram A

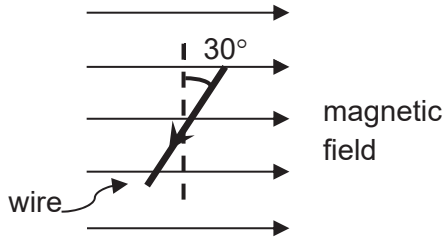


diagram B

What is the direction and magnitude of the force acting on the wire?

	direction	magnitude
A	into the plane	2.0 mN
B	out of the plane	2.0 mN
C	into the plane	3.5 mN
D	out of the plane	3.5 mN

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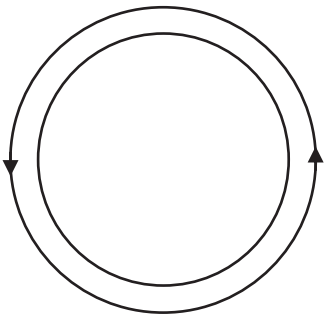
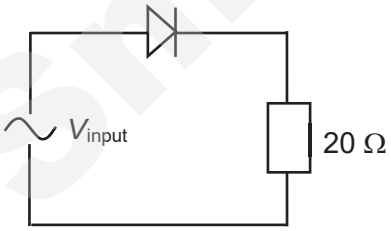
27 A small circular coil lies inside a big coil as shown. These two coils are horizontal and concentric. When an anti-clockwise current flows through the big coil suddenly, the small coil experiences an induced current at the same instant.

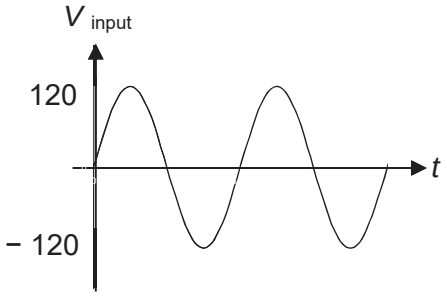


Which of the following describes the direction of the induced current in the small coil and its effect on the size of the small coil?

	direction of induced current	effect on size of small coil
A	clockwise	smaller
B	clockwise	bigger
C	anti-clockwise	smaller
D	anti-clockwise	bigger

28 An alternating input voltage is connected across a 20 Ω resistor through a rectifying diode.





What is the mean rate of heat dissipated in the resistor?

A 0 W **B** 180 W **C** 360 W **D** 720 W

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29 Light falls on a metal surface and emits photoelectrons by photoelectric effect. If the frequency of the light is doubled while keeping the intensity of the light constant,

A the stopping potential will also be doubled, if the metal remains unchanged.

B the photoelectric current will be reduced by half.

C the threshold frequency of the metal also needs to be doubled so that the maximum kinetic energy of the photoelectrons remains unchanged.

D the maximum speed of the photoelectrons will also be doubled, if the metal remains unchanged.

30 At time t = 0, there are 7.0×10^{11} atoms of a radioactive element U of half-life 14 hours in a container.

After time t ', the number of atoms inside the container is 6.03×10^{11}. K number of atoms of U are then added to the container. The activity of the radioactive source from the container is found to be 3.62×10^{6} Bq after 27 hours from time t '. The value of K is

A 3.99×10^{11} **B** 4.62×10^{11} **C** 6.03×10^{11} **D** 6.34×10^{11}

--- End of paper ---

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YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/2**
HIGHER 2 **25th August 2017**
2 hours

Paper 2 Structured Questions

Candidates answer on the Question Paper.
No Additional Materials are required.

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READ THESE INSTRUCTIONS FIRST

Write your name and CTG in the spaces provided on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
For numerical answers, **all** working should be shown clearly.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 2 (30.0%)	
1	/3
2	/4
3	/5
4	/5
5	/9
6	/10
7	/11
8	/8
9	/5
10	/20
Penalty	
Total	
	/ 80

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This question paper consists of 19 printed pages.

For Examiner's Use

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o nI$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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1 The density of the material of a rectangular block was determined by measuring the mass and linear dimensions of the block. Below shows the measurements obtained, together with their absolute uncertainties.

- mass = (25.0 ± 0.1) g
- length = (5.00 ± 0.01) cm
- breadth = (2.00 ± 0.01) cm
- height = (1.00 ± 0.01) cm

The density, ρ was calculated to be 2.500 g cm^{-3}.
Express the value of ρ together with its absolute uncertainty $\Delta\rho$.

($\rho \pm \Delta\rho$) = (…… ± ……) g cm^{-3} [3]

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2 The variation of the force F with time t acting on a body of mass 200 g is as shown in Fig. 2.1.

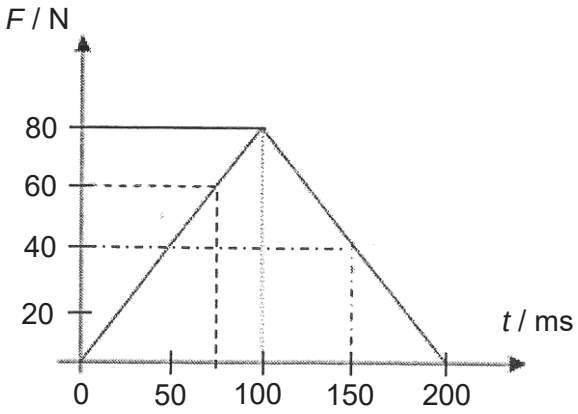

Fig. 2.1

(a) With reference to Fig. 2.1, calculate the change in momentum of the body from t = 100 ms to t = 150 ms.

change in momentum = ……..kg m s^{-1} [2]

(b) Using your answer in **(a)** or otherwise, calculate the velocity of the body at t = 150 ms, given that the velocity of the body at t = 100 ms is 15 m s^{-1}.

velocity = …….. m s^{-1} [2]

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3 A block of mass 12 kg is released from rest and slides down a 30° frictionless incline plane as shown in Fig. 3.1. It is stopped by a spring with spring constant, *k*.

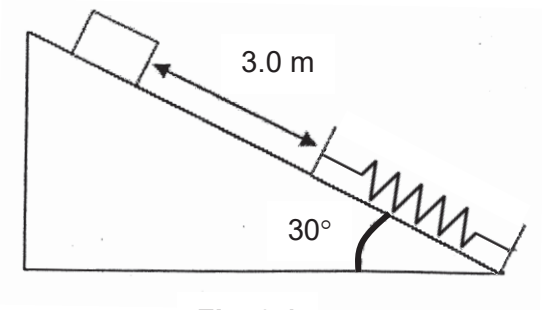

Fig. 3.1

The initial distance between the point of release and the uncompressed spring is 3.0 m. After the block comes to rest momentarily, the spring is compressed by 1.3 m.

(a) Describe the energy transformation from the time the block is released from rest to the time whereby the spring is compressed by 1.3 m.

……

……

……

……

……

……

……

……

…… [3]

(b) Calculate the value of *k*.

k = …… N m^{-1} [2]

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For Examiner's Use

4 Part of an arch bridge made of stone is shown in Fig. 4.1.

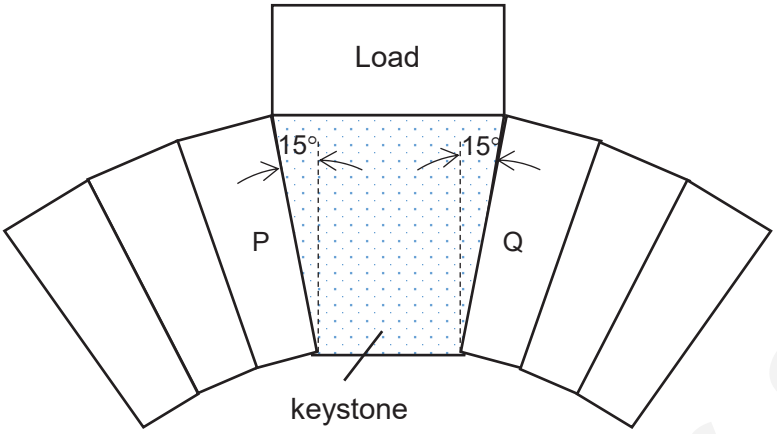

Fig. 4.1

The central stone is known as a keystone and has a weight of 500 N. The keystone is supporting a load of 5700 N. The sides of the keystone make an angle of 15° to the vertical. The two stones P and Q, which are next to the keystone, exert forces at right angles to the sides of the keystone.

In Fig. 4.2, the vector *L* represents the force the load exerts on the keystone to a scale of 1 cm : 1000 N. By completing the scaled vector diagram for the system of forces acting on the keystone, determine the value of the force that stone P exerts on the keystone.

Label your forces clearly.



Fig. 4.2

Force exerted by stone P = …… N [5]

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5 **(a)** A plastic container is filled with 2.5 kg of water at a temperature of 30 °C. Two students decided to add 500 g of ice cubes at – 5.0 °C and 200 g of steam at 100 °C to the container of water simultaneously, to investigate their combined effect on the temperature of water.

Assuming that there is no heat gain or loss to the surrounding and plastic container, and given the following values:

- Latent heat of fusion of ice = 3.33×10^5 J kg^{-1}
- Latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}
- Specific heat capacity of water = 4.20×10^3 J kg^{-1} K^{-1}
- Specific heat capacity of ice = 2.05×10^3 J kg^{-1} K^{-1}

Determine the final temperature of water in the container.

final temperature = …… °C [4]

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(b) State the *first law of thermodynamics*.

……

……

…… [2]

(c) On a warm afternoon, two identical bubbles of ideal gas rise from the bottom of a pond to the surface. As the water pressure is much lower at the surface of the pond compared to the bottom, the bubbles expand as they rise. However, bubble A rises very quickly so that there is no heat exchange between it and the water. On the other hand, bubble B does not rise as quickly because it is slowed down by water plants and as a result, its temperature always remains in thermal equilibrium with the water.

State and explain which of the two bubbles, A or B, will be larger by the time they reach the surface of pond.

……

……

……

……

……

……

…… [3]

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6 **(a)** A string, tied to a sinusoidal oscillator at P and running over a support at Q, is stretched by a block of mass *m* as shown in Fig. 6.1. The amplitude of the motion at P is small enough for that point to be considered a node. A node also exists at Q.

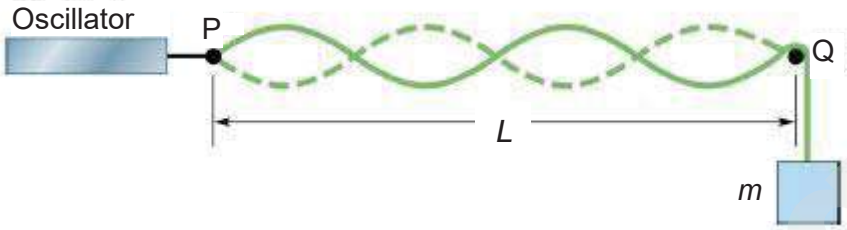

Fig. 6.1

(i) Explain how stationary waves are formed along the string.

……..

……..

……..

…….. [2]

(ii) In terms of phase change, explain why a node is formed at Q.

……..

……..

…….. [2]

(iii) The frequency of the oscillator is set at 120 Hz. A stationary wave is formed when the length *L* is 1.20 m. The maximum amplitude of the antinode is 0.80 cm. The length is slowly increased and the stationary wave disappears. The stationary wave is again formed when *L* is increased by 0.30 m.

1. Determine the velocity of the wave in the string.

velocity = …….. m s^{-1} [2]

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2. Point X is at one of the antinodes when L is 1.50 m. Point Y is at a distance $\lambda/8$ away from point X, where λ is the wavelength of the wave.

Determine the phase difference between the two points.

phase difference = …….. rad [1]

(b) A car, with its headlights turned on, is approaching a camera which has an aperture that receives light into its body. Photographs of the two headlights are taken at several time intervals.

Explain why when the car is far away, the headlights are barely distinguishable whereas when the car is nearer, the headlights can be seen as separate entities in the photographs.

……

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……

……

…… [3]

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For Examiner's Use

7 **(a)** Define *electric potential* at a point in an electric field.

……

……

…… [1]

(b) Point charges P and Q of +6.0 μC and −9.0 μC respectively are placed 50 mm apart along a straight line as shown in Fig. 7.1. Along the straight line, there is a neutral point where there is no net electric strength.



Fig. 7.1

(i) Indicate the position of the neutral point along the straight line in Fig. 7.1, by putting a cross and "N". [1]

(ii) Determine the separation between the neutral point and point charge P.

separation = …….. m [2]

(iii) Calculate the work done to move point charge P to the neutral point.

work done = …….. J [2]

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(c) As shown in Fig. 7.2, a charged sphere of mass 5.0 g and charge −2.5 mC is held in between two parallel plates of +4.0 V and –1.0 V placed 10 cm apart. When the sphere is released from rest, it experiences acceleration due to the forces acting on it.

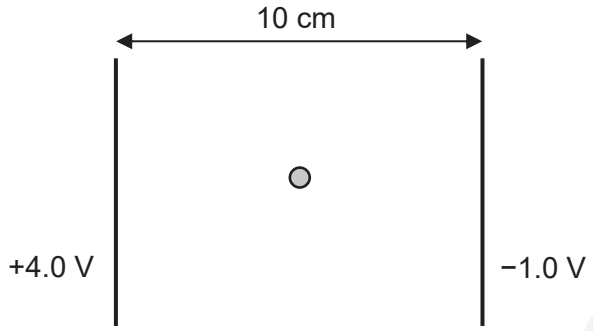

Fig. 7.2

(i) Determine the acceleration of the sphere upon release.

acceleration = …….. m s^{-2} [2]

(ii) Hence calculate the displacement of the sphere after 50 ms upon release.

displacement = …….. cm

direction of displacement = …….. [3]

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8 **(a)** The I-V characteristic graph of a given tungsten filament lamp is shown in the Fig. 8.1.

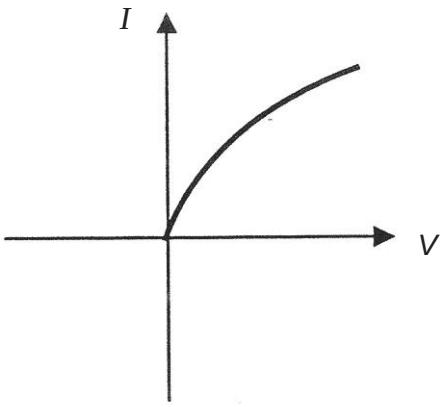

Fig. 8.1

With the aid of a labelled diagram, describe how the above I-V characteristic graph can be obtained.

……

……

……

……

……

……

……

…… [4]

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(b) A high potential is applied between the electrodes of a gas discharge tube so that the gas is ionised (both electrons and positive charged particles are present). The gas carries a current of 8.16 mA and the number of electrons passing any point in the gas per unit time is 2.58×10^{16} s^{-1}.

(i) Calculate the current due to the electrons.

current = ……..A [2]

(ii) If the charge on each positively charged particle is 3.2×10^{-19} C, determine the number of positively charged particles passing any point in the gas per unit time.

number per unit time = ……..s^{-1} [2]

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9 A light source of power 1.2 W gives out monochromatic light of wavelength 530 nm. The light is incident on a metal surface which has a work function of 1.9 eV.

(a) Determine the rate of photons incident on the metal surface.

rate of photons = ... s^{-1} [2]

(b) Determine whether photoelectrons will be emitted from the metal surface.

..... [1]

(c) Assuming that all photons are incident normally to the metal surface of area 3.8×10^{-6} m^2 and absorbed by the metal, calculate the radiation pressure acting on the surface.

radiation pressure = ... Pa [2]

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10 X-rays are emitted when a metal target is bombarded by high energy electrons. The X-ray spectrum consists of a broad continuous spectrum and a series of sharp lines known as the line or characteristic X-ray spectrum as shown in Fig. 10.1.

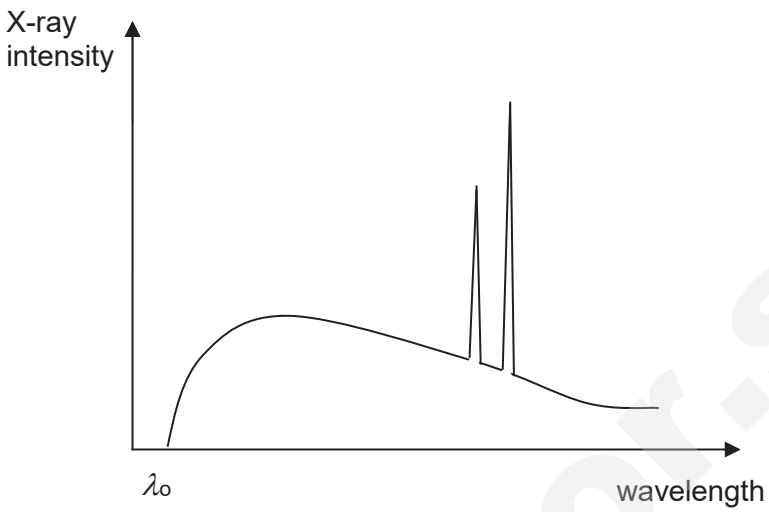

Fig. 10.1

(a) **(i)** Explain how the continuous spectrum is formed.

……

……

……

…… [2]

(ii) Explain why there is a minimum wavelength λ_o for the continuous spectrum.

……

……

…… [1]

(b) In 1913, a British physicist Henry G.J, Moseley measured the wavelength of the characteristic X-rays from a number of elements. He noted that for a particular type of emitted X-ray, the frequency *f* varied in a regular way with the atomic number *Z* of the element according to an empirical relation, known as Moseley's law:

$$f = a(Z - b)^2,$$

where *a* and *b* are positive constants, and *Z* is the atomic number.

In multiple-electron atoms, the energy of an electron in any shell (measured in electron−volts) is given by:

$$E_n = -\frac{13.6(Z_{eff,n})^2}{n^2}$$

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where

Shell	n	Maximum no. of electrons in shell
K	1	2
L	2	8
M	3	8

$Z_{eff,n}$ is used instead of atomic number Z because of the shielding effect of the orbital electrons beneath the nth shell when n > 1. $Z_{eff,n}$ can be computed by:

$Z_{eff,n}$ = Z for n = 1

= Z – number of electrons present in all shells below the nth shell, for n > 1

(i) Suggest what is meant by an *empirical relation*.

……

……

…… [1]

(ii) Determine the units of constants a and b.

units of a = ……..

units of b = …….. [1]

(iii) Suggest why a material with a large atomic number is preferred over one with smaller atomic number in the production of X-rays.

……

……

…… [1]

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(c) **(i)** In the space below, sketch the graph of $\sqrt{f}$ against Z for positive values of $\sqrt{f}$. Show clearly how the relationship for the graph is derived. [2]

(ii) Use the graph to explain how energy of a particular type of X-rays from elements is related to atomic number of the elements.

……

……

…… [2]

(d) When an electron which has been accelerated through a large potential strikes a tungsten target (Z = 74), it can displace an electron in the K-shell, leaving behind a vacancy. A characteristic X-ray photon will be emitted if an electron from the M-shell drops into the vacancy.

(i) Calculate the energy of an electron in the K-shell.

energy of electron = …… J [2]

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(ii) Calculate the energy of the X ray photon that is produced from the transition of an electron from the M shell after an electron from the K-shell has been displaced.

energy of X-ray photon = …….. J [5]

(e) **(i)** The characteristic lines in Fig. 10.1 are formed either due to an electron transition from the L-shell to the K-shell (K_α), or due to a transition from the M-shell to the K-shell (K_β).

Label, in Fig. 10.1, the 2 transitions K_α and K_β. [1]

(ii) Suggest why the intensity of one of the peaks is higher than the other.

……

……

……

……

…… [2]

--- End of paper ---

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YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/3**
HIGHER 2 **13th September 2017**
2 hours

Paper 3 Longer Structured Questions

Candidates answer on the Question Paper.
No Additional Materials are required.

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READ THESE INSTRUCTIONS FIRST

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Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

Write your answers in the spaces provided on the question paper.
For numerical answers, **all** working should be shown clearly.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 1 (15%)	
	/30
Paper 2 (30%)	
	/80
Paper 3 (35%)	
Section A	
1	**/10**
2	**/10**
3	**/10**
4	**/10**
5	**/10**
6	**/10**
Section B	
7	**/20**
8	**/20**
Penalty	
	/ 80
Paper 4 (20%)	
	/ 55
Overall Percentage (%)	

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This question paper consists of 25 printed pages.

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

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hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o nI$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

Answer **all** the questions in the spaces provided.

1 A stone is projected with a speed of 5.0 m s^{-1} from a cliff on a faraway planet. It travels from point A, through point B and to point D as shown in Fig. 1.1.

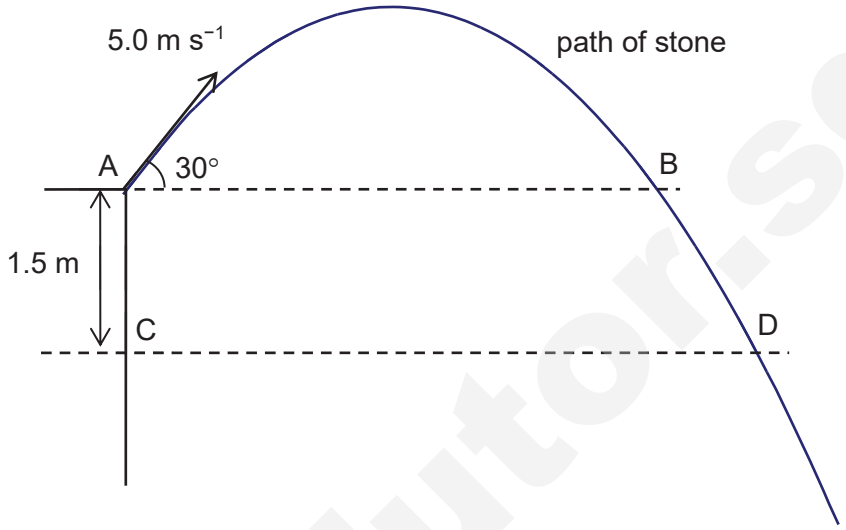

Fig. 1.1

Fig. 1.2 shows the variation of the stone's vertical velocity v with time t.

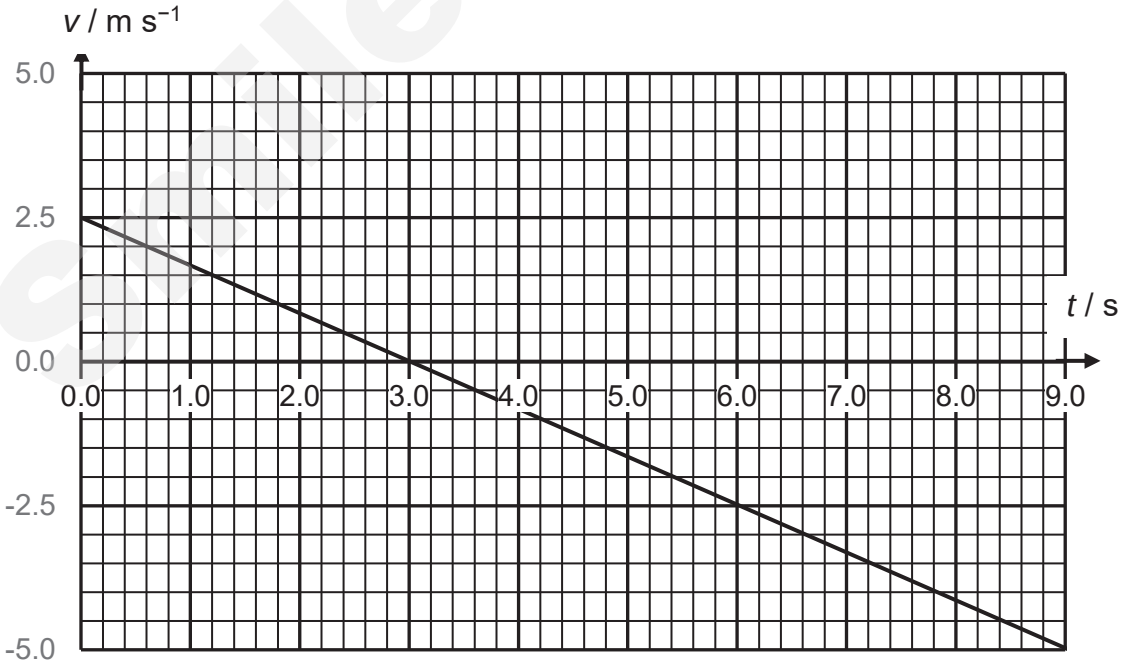

Fig. 1.2

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(a) Determine the acceleration in the vertical direction.

acceleration = ... m s^{-2} [1]

(b) Determine the vertical velocity of the stone at point D.

vertical velocity = ... m s^{-1} [2]

(c) Shade in Fig. 1.2, the area corresponding to the vertical displacement between point B and D. [2]

(d) Mark on the line with ' **X** ' in Fig. 1.2, the instant when the stone is moving 45° to the horizontal axis. Explain how you derived your answer clearly in the space provided below.

[3]

(e) Sketch in Fig. 1.2, the variation of the stone's vertical velocity with time when the effect of air resistance is not negligible. [2]

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For Examiner's Use

2 **(a)** State the principle of conservation of momentum of a system.

……

……

…… [2]

(b) A 0.0200 kg object travelling towards the right at 8.0 m s^{-1} collides head on with another 0.0100 kg object travelling towards the right at 5.0 m s^{-1}. After collision, the 0.0200 kg object travels towards the left at 2.0 m s^{-1}.

(i) State what is meant by **head on** collision in this context.

……

……

…… [1]

(ii) Calculate the speed of the 0.0100 kg object after collision.

speed = …….. m s^{-1} [2]

(iii) State the direction of motion of the 0.0100 kg object after collision.

direction: ……. [1]

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(iv) If the impact time is 0.120 s, calculate the average force exerted on the 0.0100 kg object by the 0.0200 kg object during collision.

force = …….. N [2]

(v) Explain why it is not possible for both objects to stop at the same instant during the collision.

……

……

……

……

……

…… [2]

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3 Fig. 3.1 shows the variation with height h near the Earth's surface of the gravitational potential ϕ.

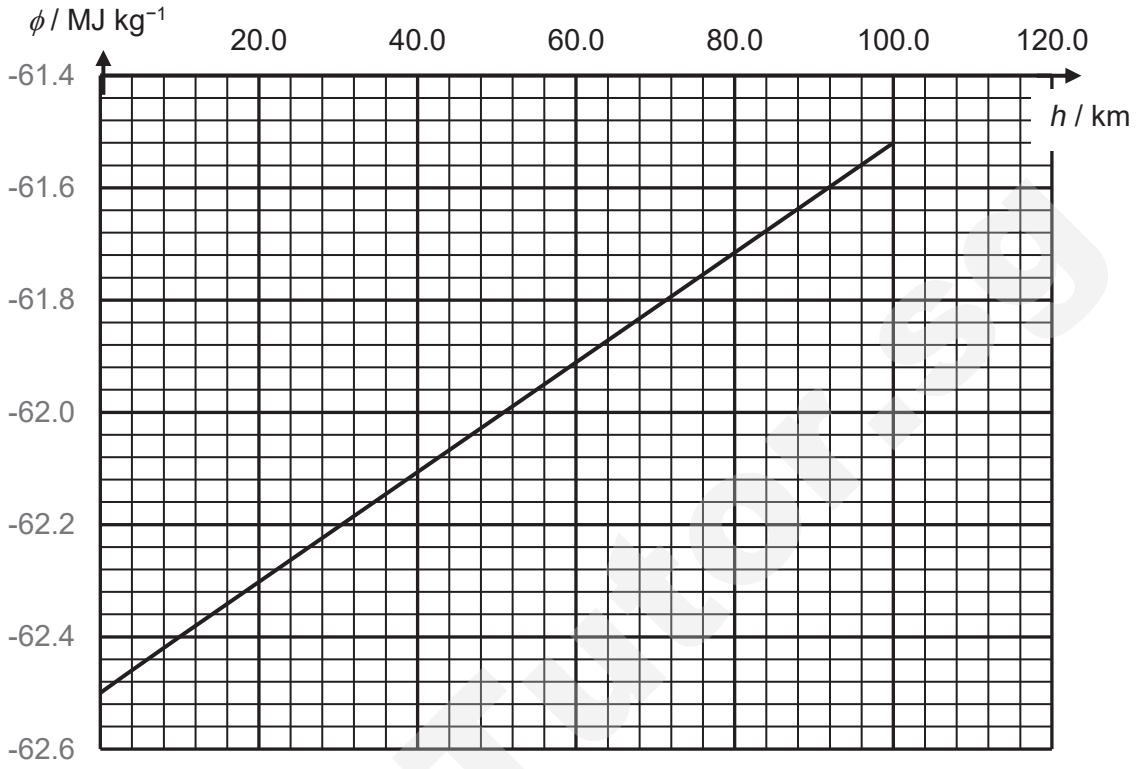

Fig. 3.1

(a) Explain how the graph shows that the gravitational field strength is approximately constant near the Earth's surface.

……

……

…… [2]

(b) A space shuttle of mass 4200 kg is moved from a height of 10 km to 100 km above the Earth's surface. Using the values from the graph, calculate the work done on the shuttle.

work done = …….. J [2]

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(c) The space shuttle is made to orbit with an angular velocity of 1.2×10^{-3} rad s^{-1} around the Earth at a height of 100 km above the Earth's surface. The gravitational field strength at that height is 9.7 N kg^{-1}.

(i) Determine the period of the space shuttle.

period = …….. s [1]

(ii) Determine the radius of the Earth.

radius = …….. m [2]

(d) Another space shuttle of different mass is made to orbit around the moon at a height such that its distance from the centre of the moon is the same as the distance of the space shuttle in **(c)** from the centre of the Earth.

Explain how the period of this shuttle would be compared to the period of the shuttle in **(c)**.

……

……

……

……

……

…… [3]

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4 **(a)** The defining equation for simple harmonic motion is

$$a = -\omega^2 x$$

(i) State the relation between ω and the frequency *f*.

……..... [1]

(ii) State the significance of the negative (−) sign in the equation.

……..

……..... [1]

(b) A frictionless trolley of mass m is held on a smooth horizontal surface by means of two similar springs each of spring constant *k*. The springs are attached to fixed points, as illustrated in Fig. 4.1.

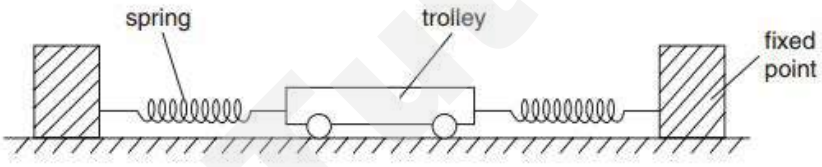

Fig. 4.1

When the trolley is in equilibrium, the extension of each spring is *e*.

The trolley is then displaced a small distance *x* to the right along the axis of the springs.

(i) Show that the magnitude *F* of the restoring force acting on the trolley is given by

$$F = 2kx$$

[2]

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(ii) The trolley is then released. Show that the angular frequency, ω of the trolley is given by

$$\omega^2 = \frac{2k}{m}$$

[2]

(c) Fig. 4.2 shows two identical polarising filters, A and B, and an unpolarised light source. The arrows indicate the plane is which the electric field of the wave oscillates.

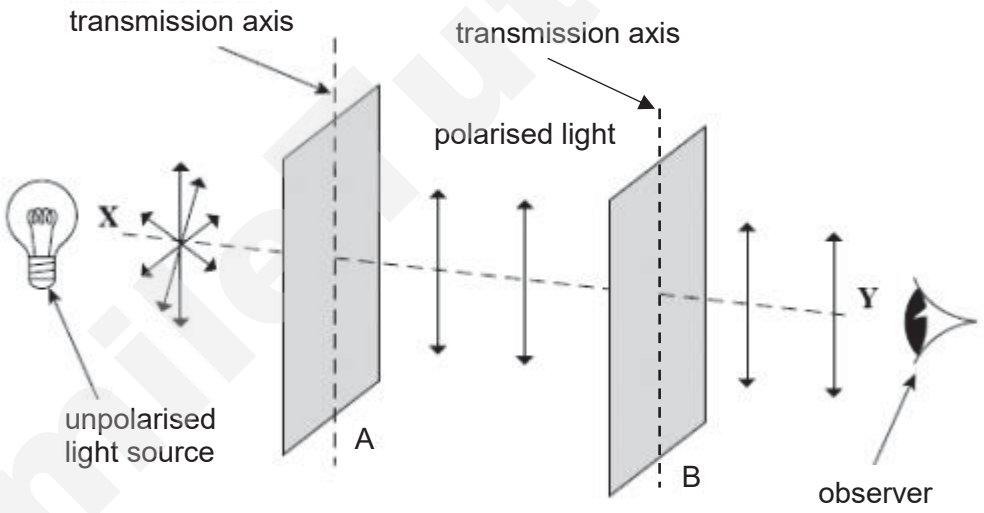

Fig. 4.2

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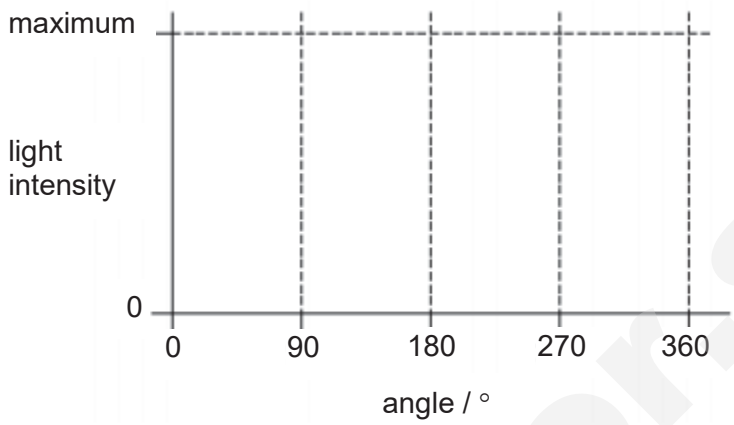
(i) The polarising filter B is then rotated clockwise through 360° (viewed from the observer's perspective) about the line XY from the position shown in Fig. 4.2. On the axes below, sketch how the light intensity reaching the observers varies.



[2]

(ii) State one application, other than in education, of a polarising filter.

……...

……... [1]

(iii) Explain why longitudinal wave cannot be polarised.

……...

……...

……... [1]

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For Examiner's Use

5 **(a)** Explain what is meant by *electromotive force of a source* and *potential difference between two points of a circuit*.

……

……

……

……

…… [2]

(b) The circuit in Fig. 5.1 consists of three fixed resistors, each of which has a safe power rating of 0.80 W.

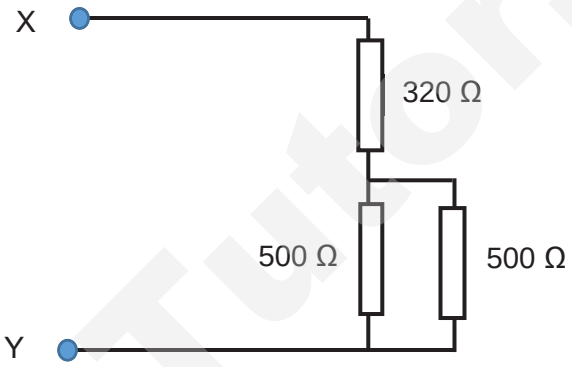

Fig. 5.1

Determine the maximum potential difference that can be applied between X and Y without damage to any of the resistor.

maximum potential difference = ……V [4]

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(c) A car battery is used to power up four lamps as shown in Fig. 5.2. The resistance of each lamp should be 180 Ω when it is working under normal conditions.

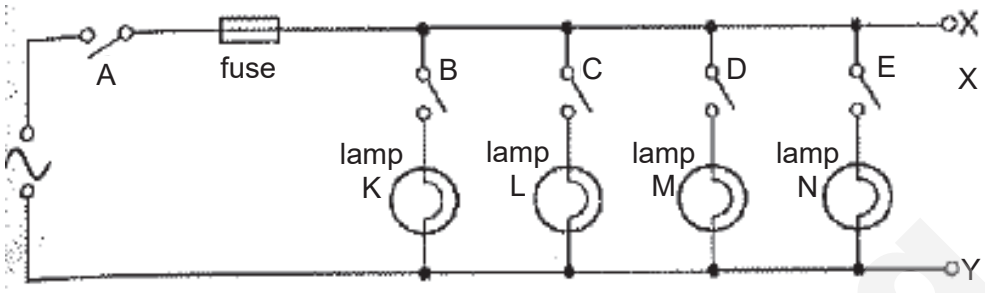

Fig. 5.2

A fault is discovered in the circuit, so switch A is open and the fuse is removed for safety. An electrician uses a resistance meter, an equipment which can be used to measure the effective resistance across any two points in a circuit, to check the lamps. He connected the resistance meter between the points X and Y and the readings obtained for different switch positions are shown in Fig. 5.3.

Switches					
A	B	C	D	E	Resistance meter reading/Ω
open	open	open	open	open	14 000 000
open	open	open	open	closed	180
open	open	open	closed	closed	90
open	open	closed	closed	closed	60
open	closed	closed	closed	closed	0.2

Fig. 5.3

(i) Based on the readings in Fig. 5.3, explain which lamp is faulty in the circuit. Show your workings clearly.

faulty lamp = …….. [2]

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(ii) Suggest what could have happened to the faulty lamp.

……..

…….. [1]

(iii) Suggest why there is still a reading of 14 MΩ on the resistance meter when all the switches are open.

……..

……..

…….. [1]

6 **(a)** Define *magnetic flux density*.

……

……

…… [1]

(b) An electron moving with a speed *v* in a magnetic field of flux density *B*, will experience a magnetic force *F*. By means of a simple diagram, show the relative directions of *F*, *B* and *v*. Write an equation for the magnitude of the force experienced relating to your diagram.

…… [3]

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(c) In 1879, the American physicist E. H. Hall found that when a current, I was flowing in a conductor, a magnetic field at right angles to the current caused a very small potential difference to be induced across the conductor of depth, *d* and width, *w*. This discovery led to the invention of a hall probe.

Fig. 6.1 shows the diagram of how a simple hall probe works.

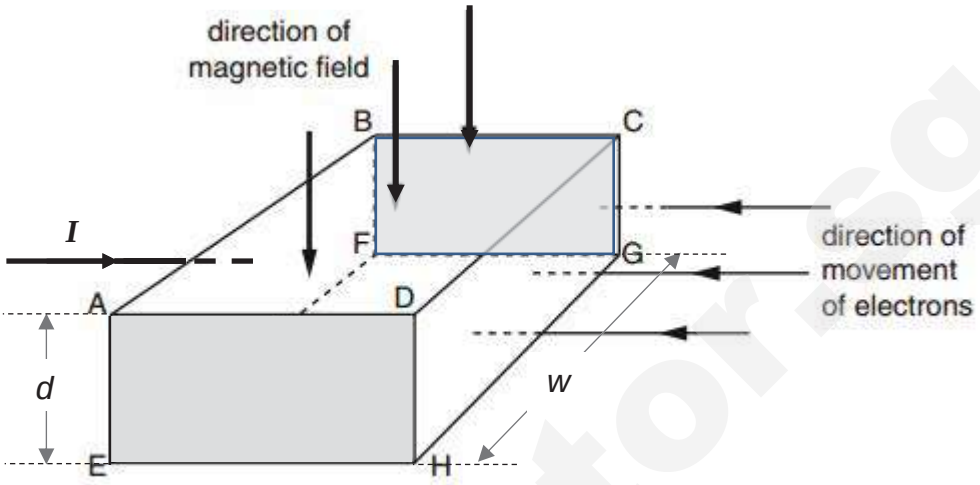

Fig. 6.1

The magnetic field is normal to face ABCD in the downward direction.

Electrons enter face CDHG at right-angles to the face. As the electrons pass through the conductor, they experience a force due to the magnetic field.

As electrons drift across the conductor at a certain drift velocity *v,* an electric field will be set up.

(i) By considering the movement of the electrons, explain why a potential difference (the Hall potential difference) exists between the shaded faces of the conductor.

……

……

…… [1]

(ii) Hence or otherwise, deduce the polarity of the potential difference by stating which face (ADHE or BCGF) has a positive potential.

…… [1]

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(iii) By considering the magnitude and direction of the electric force and magnetic force acting on the electrons, show that the magnitude of the Hall potential difference, V_H is

$$V_H = \frac{IB}{ned}$$

where

n is the number of free electrons per unit volume in the conductor

e is the elementary charge of electron

d is the depth of conductor

B is the magnetic flux density

I is the current flowing through the conductor

[3]

(d) Experiments to demonstrate the Hall effect normally involve the use of a semiconductor sample instead of metallic conductor. Suggest a reason.

……

……

…… [1]

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Section B

Answer any **one** question from this Section in the spaces provided.

7 **(a)** State *Lenz's law*.

……

……

…… [1]

(b) A pair of parallel metal rails of negligible resistance are placed 12 cm apart in an uniform magnetic field of strength 0.65 T applied perpendicularly to the rails out of paper, as shown in Fig. 7.1. Two 15 cm long metal rods, AB and CD, are placed on top of the rails and can slide smoothly along the rails. Rod AB has an electrical resistance of 8.0 Ω while rod CD has an electrical resistance of 10 Ω. Rod AB is pulled to the left by an external force at a constant speed of 2.0 m s^{-1} while rod CD is pulled to the right at a constant speed of 3.0 m s^{-1}.

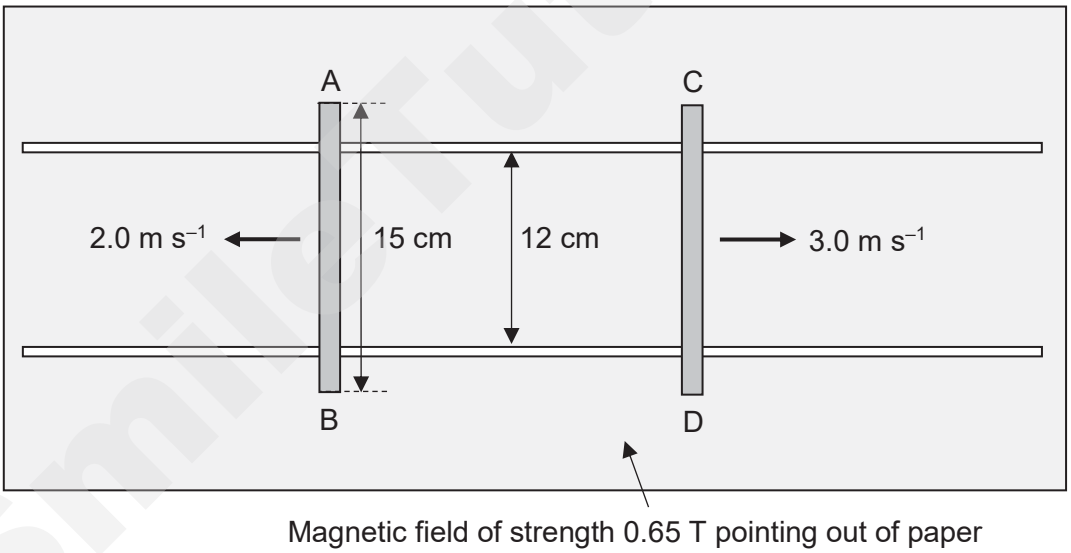

Fig. 7.1

(i) State which end of rods AB and CD has a higher potential.

Rod AB: …….

Rod CD: ……. [2]

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(ii) Determine the induced e.m.f. across each rod.

e.m.f. of rod AB = ... V

e.m.f. of rod CD = ... V [2]

(iii) Determine the induced current flowing in the rods.

induced current = ... A [2]

(iv) Hence calculate the total power dissipated in both rods.

total power = ... W [2]

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(v) By considering your answer in **(iv)**, show that energy is conserved during this induction process.

.....

.....

..... [3]

(c) State what is meant by *root-mean-square current*.

.....

.....

..... [1]

(d) An ideal transformer is used to step up an alternating voltage V_{in} as shown in Fig. 7.2. The secondary coil of the transformer is connected to a resistor of 4.0 Ω.

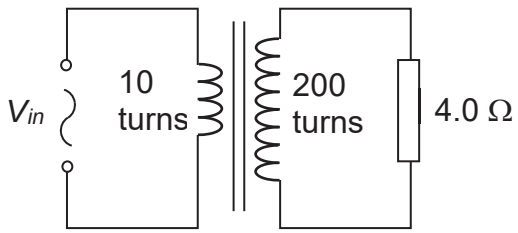

Fig. 7.2

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Fig. 7.3 shows the variation of the power input at the primary coil with respect to time *t*.

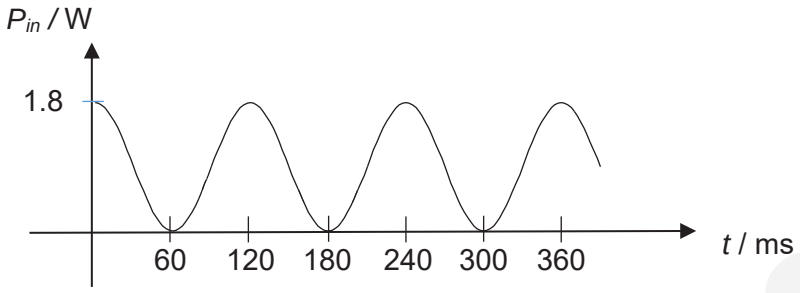

Fig. 7.3

(i) Determine the root-mean-square voltage in the secondary coil.

root-mean-square voltage = ... V [2]

(ii) Determine the root-mean-square current flowing in the primary coil.

root-mean-square current = ... A [2]

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(iii) Sketch the variation of input current I_{in} at the primary coil with respect to time t, in Fig. 7.4 and indicate the value of peak input current. [2]

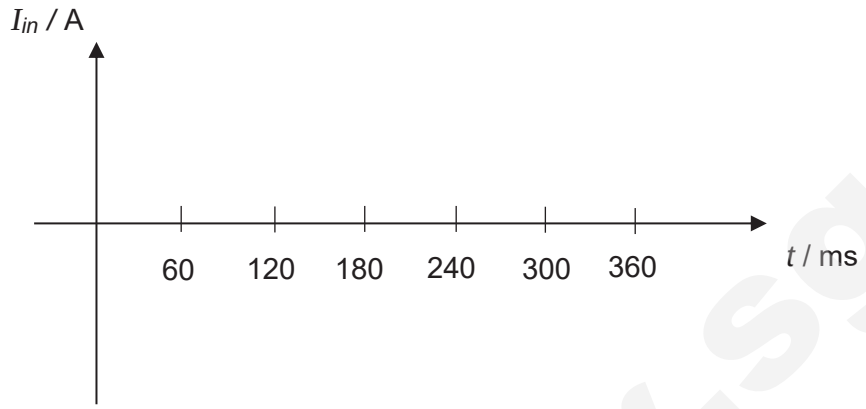

Fig. 7.4

(iv) State the equation showing how input current I_{in} varies with time t.

……

…… [1]

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For Examiner's Use

8 **(a)** Explain what is meant by

(i) *half-life* of a radioactive isotope

……

……

…… [1]

(ii) the *decay constant*

……

……

…… [1]

(iii) *random* nature of the radioactive decay

……

……

…… [1]

(b) A milk sample is to be tested for evidence of radioactive contamination with the radioactive nuclide strontium-90, using a Geiger-Muller tube. The two stages involved in the decay of strontium-90 are described by the equations:

Stage 1: $^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + \beta$

Stage 2: $^{90}_{39}Y \rightarrow {}^{90}_{40}Zr + \beta$

At each stage, a beta particle is emitted. The half-life for the second stage is 64 hours and the final product zirconium-90 is stable.

The decay constant for the beta decay of strontium-90 is 7.75×10^{-10} s^{-1}.

Data:

Mass of Strontium-90	89.907738 u
Mass of Yttrium-90	89.907150 u
Mass of beta particle	0.0005485 u

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(i) Given that the parent strontium-90 nucleus is initially at rest, calculate the speeds of the two daughter products in Stage 1.

speed of Yttrium: ..... m s^{-1}

speed of beta particle: ..... m s^{-1} [4]

(ii) State and explain the difficulties involved in attempting to measure the half-life of the beta decay of the strontium-90 experimentally.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

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(iii) State two precautions that must be taken in order to obtain an accurate value of the activity of the milk sample.

……

……

……

……

…… [2]

(iv) Explain why and how it is dangerous for human, particularly pregnant ladies, to be exposed to the above radioactive product.

……

……

……

……

……

……

…… [3]

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(v) Suppose a beta particle from the strontium-90 decay moves in a gas along a straight line OA. A uniform magnetic flux density 3.0×10^{-4} T is applied when the particle reaches A. Fig. 8.1 shows the subsequent path of the particle in a plane perpendicular to the magnetic field.

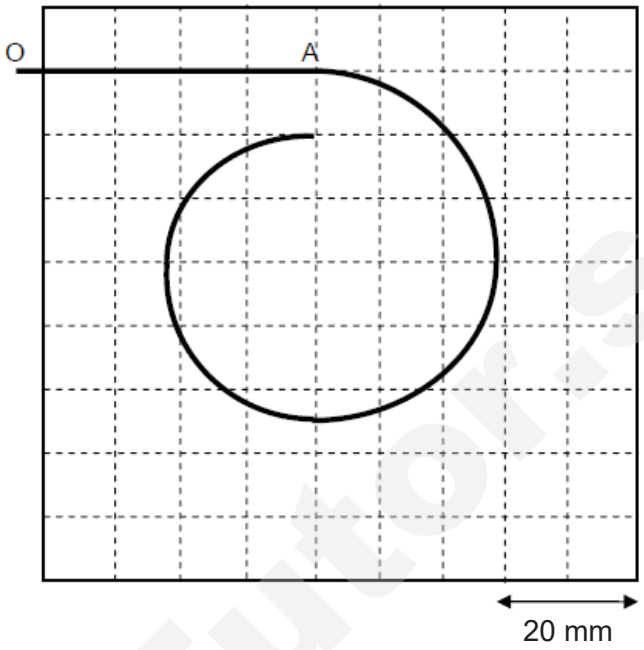

Fig. 8.1

1. State the direction of the applied magnetic field.

……..…… [1]

2. Explain why the path of the beta particle is a spiral.

……..……

……..…

……... [2]

3. By estimating the radius of the curvature at A using Fig. 8.1, calculate the speed of the particle as it passes A.

speed = …… m s^{-1} [2]

--- End of paper ---

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Candidate's name …… CTG ……

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2017

PHYSICS
HIGHER 2

9749/4
18th August 2017
2 hours 30 minutes

Paper 4 Practical Test

Candidates answer on the Question Paper.
No Additional Materials are required.

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READ THESE INSTRUCTIONS FIRST

Write your name and CTG in the spaces provided on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.

Shift
Laboratory

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1	/13
2	/10
3	/20
4	/12
Total	
	/ 55

The number of marks is given in brackets [ ] at the end of each question or part question.

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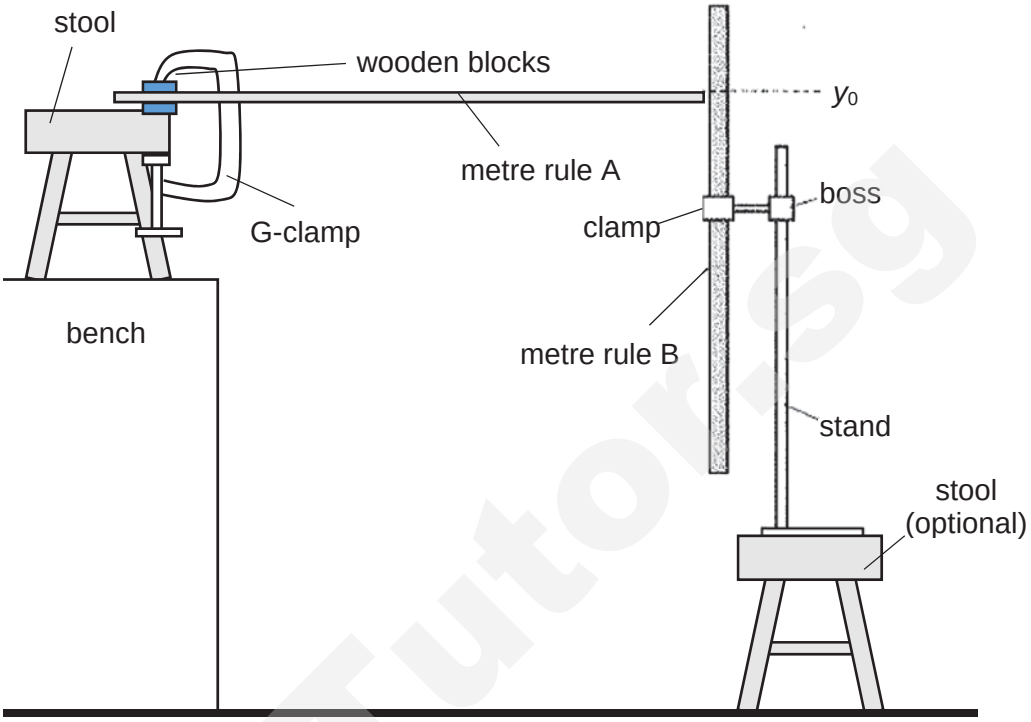
1 In this experiment, you will investigate the deflection of a loaded metre rule.

(a) **(i)** Set up the apparatus as shown in Fig. 1.1.



y_0 is the point on rule B level with the top of rule A.

Fig. 1.1

(ii) Record the reading y_0.

y_0 = ...[1]

(iii) Place a 200 g mass on the end of rule A as shown in Fig. 1.2.

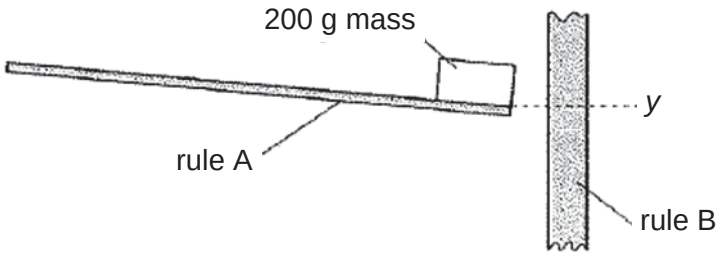


Fig. 1.2

y is the point on rule B level with the top of rule A.

(iv) Record the reading y.

y = ...[1]

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(v) Remove the 200 g mass from rule A.

(vi) Calculate the deflection $(y - y_0)$.

$(y - y_0)$ = ...[1]

(vii) Determine the percentage uncertainty in $(y - y_0)$.

percentage uncertainty in $(y - y_0)$ = ...[1]

(b) **(i)** Repeat **(a)(ii)**.

y_0 = ...

(ii) Place the 200 g mass at a position approximately half way along rule A.

(iii) Repeat **(a)(iv)**, **(a)(v)** and **(a)(vi)** with the 200 g mass placed at a position approximately half way along rule A.

y = ...

$(y - y_0)$ = ...[2]

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(c) **(i)** It is suggested that:

> "If both masses are placed on rule A in different positions at the same time, the deflection will equal the sum of the deflections for each mass on its own."

Take more readings to investigate this suggestion. Present your results in a table.

[3]

(ii) State and explain whether or not the results of your experiment support the suggestion.

……

……

……

……

……[2]

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(d) **(i)** State a significant source of error in this experiment.

……

……

……[1]

(ii) Suggest one improvement that could be made to the experiment to address the source of error identified in **(d)(i)**. You may suggest the use of other apparatus or a different procedure.

……

……

……[1]

[Total: 13 marks]

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2 In this experiment, you will investigate an oscillating rod.

(a) **(i)** You have been provided with a wooden rod with five holes.

The distance *x* is between the end of the rod and the first hole as shown in Fig. 2.1.

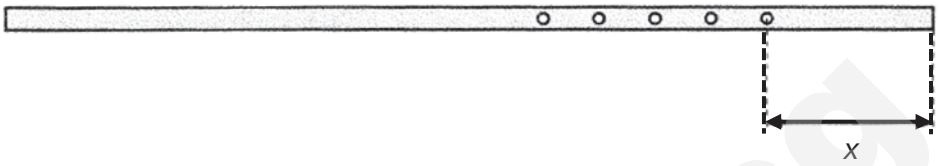

Fig. 2.1

(ii) Measure and record *x*.

x = ……[1]

(iii) Push the wooden block onto the wooden rod so that its centre is the same distance *x* from the end of the rod as shown in Fig. 2. 2.

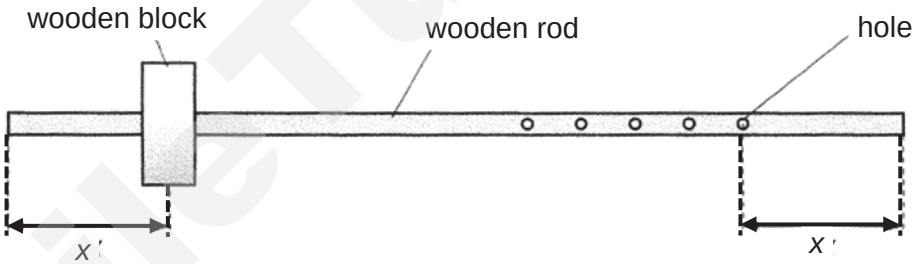

Fig. 2.2

(iv) Explain how you ensured that the distance measured between the centre of the wooden block and the end of the rod was equal to *x*.

……

……

……

……

……[1]

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(b) **(i)** Assemble the apparatus as shown in Fig. 2.3 with the nail through the first hole.

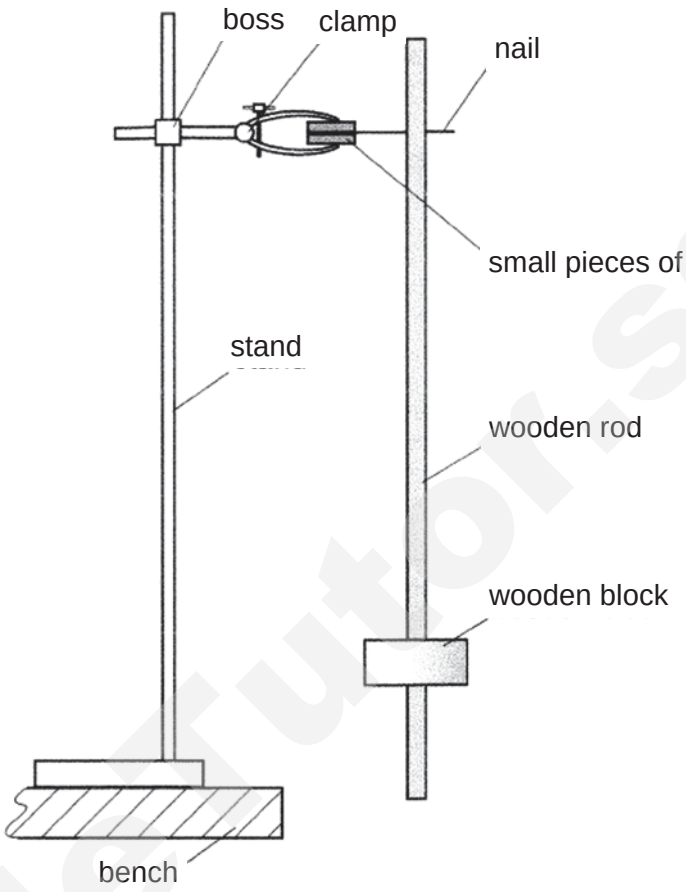

Fig. 2.3

(ii) Pull the bottom of the rod towards you.

Release the rod and allow it to oscillate.

Determine the period T of these oscillations.

T = ...[2]

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(c) **(i)** Repeat **(a)(ii)**, **(a)(iii)** and **(b)** using all the other holes.
Present your results in a table.

[4]

(ii) Estimate the value of x for which T has a minimum value.

x = ……[1]

(iii) Explain how you estimated your value of x in **(c)(ii)**.

……

……

……

……

……[1]

[Total: 10 marks]

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3 In this experiment, you will investigate constantan wire.

(a) (i) You have been provided with two lengths of constantan wire attached to mountings labelled M and N, an unknown resistor Y, and six resistors labelled with their resistance values in ohms.

Connect the circuit as shown in Fig. 3.1.

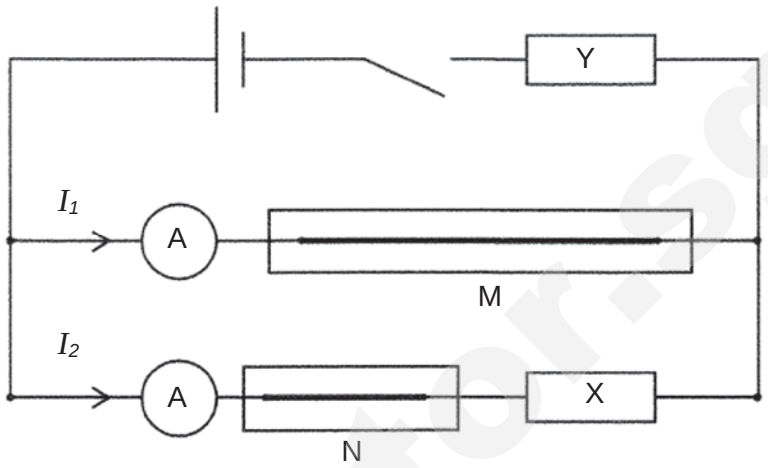

Fig. 3.1

The resistor X should be one of the resistors provided which has its value attached.

(ii) Record *R*, the resistance of X.

R = ...

(iii) When the switch is closed, the current through M is I_1 and the current through N is I_2.

Close the switch and record I_1 and I_2.

I_1 = ...[1]

I_2 = ...

(iv) Open the switch.

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(b) Change X and repeat **(a)(ii)**, **(a)(iii)** and **(a)(iv)** for further values of R.

[5]

(c) I_1, I_2 and R are related by the expression

$$\frac{I_1}{I_2} = PR + Q$$

where P and Q are constants.

(i) Draw a graph of $\frac{I_1}{I_2}$ against R.

(ii) Determine the gradient of the line.

gradient = ……[1]

(iii) Determine the y-intercept of the line.

y-intercept = ……[1]

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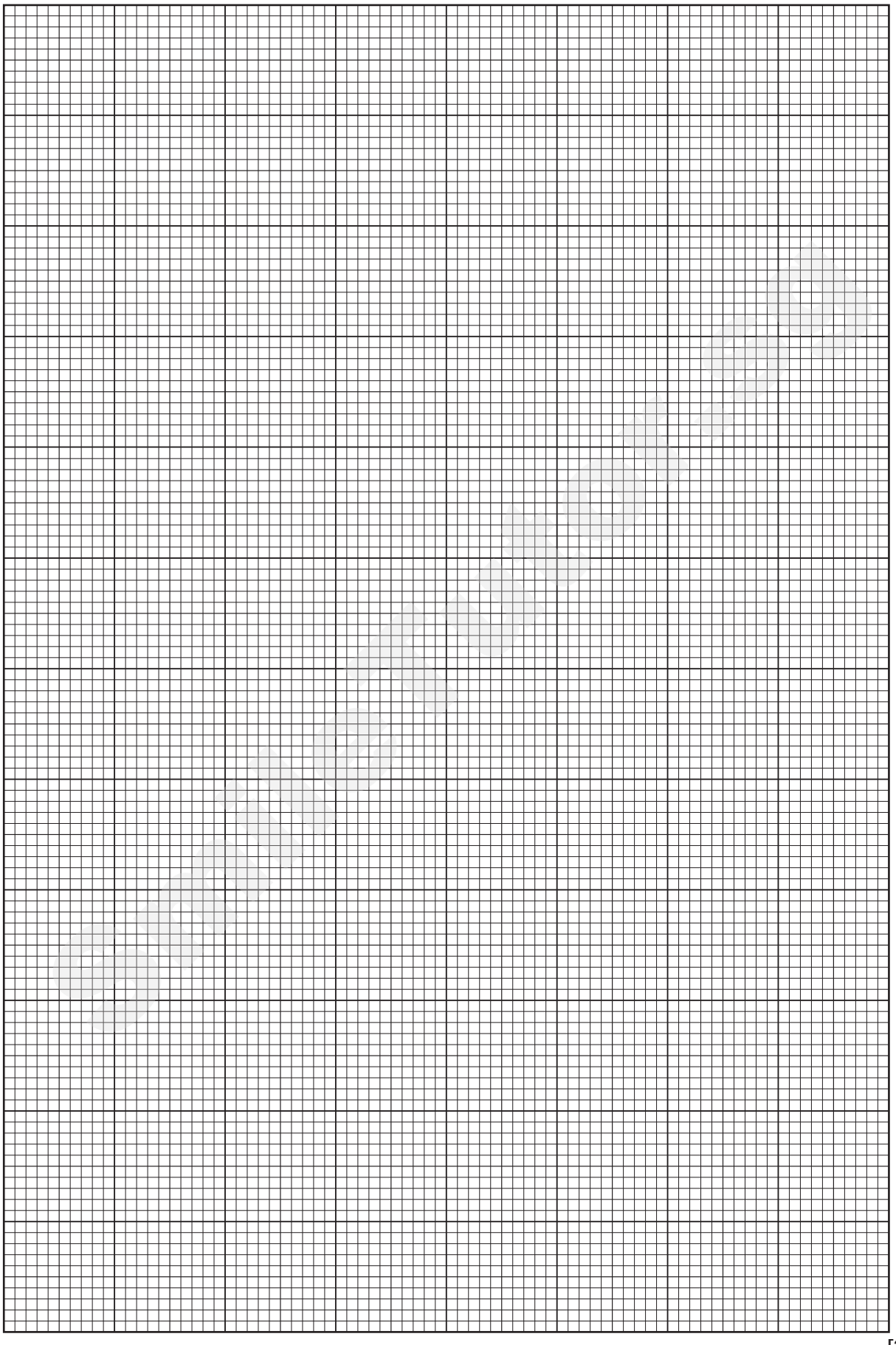

[3]

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(d) Use values from **(c)(ii)** and **(c)(iii)** to determine values for P and Q.

P = ……[1]

Q = ……[1]

(e) Standard wire gauge (swg) describes the diameter of a wire.

The data in the table shows the diameter d and resistance per metre R' for constantan wire of different swg.

swg	d / mm	R' / $\Omega\ m^{-1}$
26	0.46	3.0
28	0.38	4.4
30	0.32	6.3
32	0.27	8.3
34	0.23	11.4
36	0.19	16.8
38	0.15	27.0
40	0.12	40.0
42	0.10	62.0
44	0.081	95.0

Theory suggests that resistance of wire M = $\frac{1}{P}$.

Use the value from **(d)** and the data in the table to identify the wire used in this experiment.

Explain your reasoning.

……

……

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……

swg ……[3]

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(f) Theory suggests that $Q = \frac{\text{length of wire N}}{\text{length of wire M}}$.

Explain whether your results support the theory.

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……[2]

(g) **(i)** The experiment is repeated with the length of wire M increased but the swg of the wire used for M and N kept the same.

On the graph grid on page 11 sketch a second graph to represent the new results. Label it Z. [1]

(ii) State a problem that might arise if both wires M and N are shortened and constantan wire of an swg 26 is used.

……

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……

……

……[1]

[Total: 20 marks]

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4 An air riffle can be used to fire small metal pellets onto an absorbent material which is placed some distance away from the riffle. The faster the pellet move, the deeper it is embedded into the absorbent material.

It is suggested that the depth, *d* the pellet is embedded into the absorbent material is related to the velocity *v* of the pellet at the instant it hits the material.

Design a laboratory experiment to investigate how the depth the pellet is embedded in the absorbent material varies with the speed of the pellet.

Your answer should include a diagram and make particular reference to

(a) the equipment to be used,
(b) the procedure to be followed,
(c) how the speed of the pellets may be changed (assuming that that the pellets leave the rifle with a fixed speed),
(d) how the depth the pellet is embedded in the absorbent material is to be measured,
(e) the control of variables,
(f) any precautions that would be taken to improve the accuracy and safety of the experiment.

You may assume that the following equipment are available, together with any other standard laboratory apparatus that would be found in a school or college science laboratory.

Mounted air rifle

Connecting wires

Stopwatch

Power supply unit

Light gates and data logger

Sheets of absorbent material (e.g. cork)

Thin aluminium foil

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Diagram:

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……[12]

--- End of paper ---

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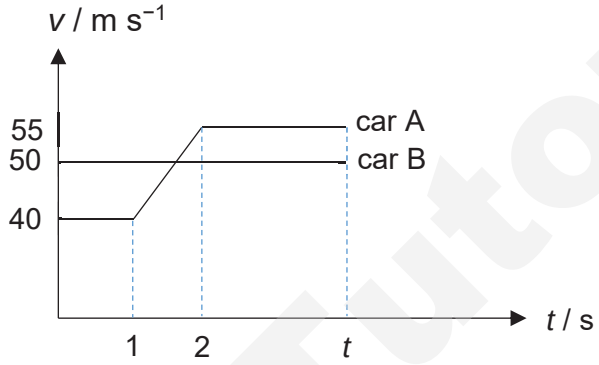
S/N	Ans	Explanation
1	D	Intensity = Power/Area = Energy/(Time × Area) [Intensity] = [Energy]/([Time] × [Area]) = ([Force] ×[displacement]/ ([Time] × [Area]) = (kg m s^{-2} × m)/(s × m^2) = kg s^{-3}
2	C	 For car A to catch up with car B, the distance travelled by both cars will be the same. $50t = (40\times1) + ½ (40+55)(1) + 55(t - 2)$ t = 4.5 s Incorrect answers Option D: If students did some careless mistakes $50t = (40\times1) + ½ (40+55)(1) + 55(t)$ t = 17.5 s Option B: did not understand the use of relative speed Distance travelled by B in 2s = 50 × 2 = 100 m Distance travelled by A in first second = 40(1) Distance travelled by A in second second = 40(1) + ½ (55-40)$(1)^2$ =47.5 m Distance between A & B = 100 – (40 + 47.5) = 12.5 m Time taken to catch up by A = 12.5 / 55 = 0.23 s (failed to see that the relative speed between A & B is 5 m s^{-1}, hence should use 12.5 / 5 = 2.5 s Total time = 2 + 0.23 = 2.2 s Option A: did not understand the question Distance travelled by B = 50t Distance travelled by A = ut + ½ $(at)^2$ = 40t + ½ (55-40)t^2 $50t = 40t + ½ (55-40)t^2$ t = 1.3 s

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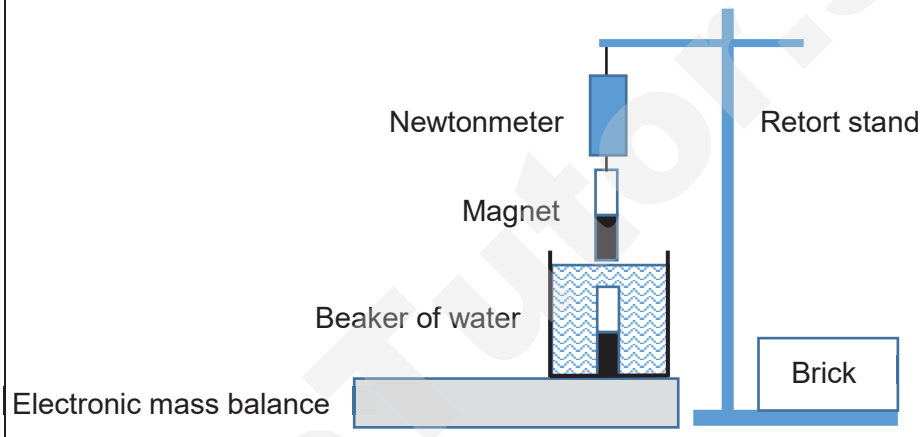
3	**C**	Vertically: $\Sigma F_y = 0$ $N - W = 0$ $N = W = 120$ N $R = \sqrt{N^2 + f^2}$ $160 = \sqrt{120^2 + f^2}$ $120^2 + f^2 = 25600$ $f = 105.83$ N Horizontally: $\Sigma F_x = m\ a_x$ $f = (W/g)\ a_x$ $105.83 = (120/9.81)\ a_x$ $a_x = 8.7$ m s^{-2}
4	**A**	 Reading = Wm + Ww – Mm Mm = T – Wm Thus reading = Wm +Ww – T + Wm = 2Wm + Ww – T. Hence reading = 2Q + J – S
5	**A**	Since the object is moving with constant velocity, there is no change in the kinetic energy of the object. Hence there is no net work down on the object.
6	**B**	$v = 100$ km h^{-1} $= (100 \times 10^3)/(60 \times 60)$ $= 27.78$ m s^{-1} By Work Energy Theorem: $\Sigma W = \Delta KE$ $P_{engine} \times t = ½\ m\ v^2 - 0$ $P_{engine} = (½\ m\ v^2)/t$ $t_{min} = (½\ m\ v^2)/\ P_{max}$ $= [((½\ (2000)\ (27.78)^2/(50 \times 10^3)$ $= 15.4$ s
7	**D**	The centripetal force is perpendicular to the displacement, hence there is no work done by the centripetal force. In time π/ω, the object would have moved half a circle. Hence the change in linear momentum = $2mv = 2mr\omega$

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8	**B**	For 1 string to support spinning motion, $T_B = mv^2/r$ For 2 string to support spinning motion, $2T_B = mv'^2/r$ V'/v = sqrt(2) V' = sqrt(2) v **Ans: B**
9	**C**	$\frac{GMm}{r^2} = mr'(\frac{2\pi}{T})^2$ $\frac{G(4.0\times10^{30})}{(2.0\times10^{11})^2} = (1.0\times10^{11})(\frac{2\pi}{T})^2$ $T = 2.4\times10^7\ s$ Incorrect answers Option A: If student thought that radius of rotation is the same as the distance between the two stars and used 1.0×10^{11} m as the radius. (1.2×10^7 s) Option B: If student thought that the centripetal force is the twice the gravitational force. (1.7×10^7 s) Option D: If student thought that radius of rotation is the same as the distance between the two stars and used 2.0×10^{11} m as the radius. (3.4×10^7 s)
10	**C**	$\frac{1}{2}mv_{esc}^2 - \frac{GMm}{r} = 0$ $v_{esc} = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2G\left(\frac{4}{3}\pi r^3\rho\right)}{r}}$ $v_{esc}\ \alpha\ r\sqrt{\rho}$ $\frac{v_{esc}planetX}{v_{esc}planetY} = \frac{R\sqrt{\rho}}{5R\sqrt{0.25\rho}}$ $v_{esc}planetY = 2.5v_{esc}planetX$ Incorrect answers Option B : careless hence chose 0.4 instead. Option A & D: when the relationship is $v_{esc} = \sqrt{\frac{2G\rho V}{r}}$ and hence $v_{esc}\ \alpha\ \sqrt{\frac{\rho}{r}}$
11	**B**	Largest area under graph and a decrease in volume

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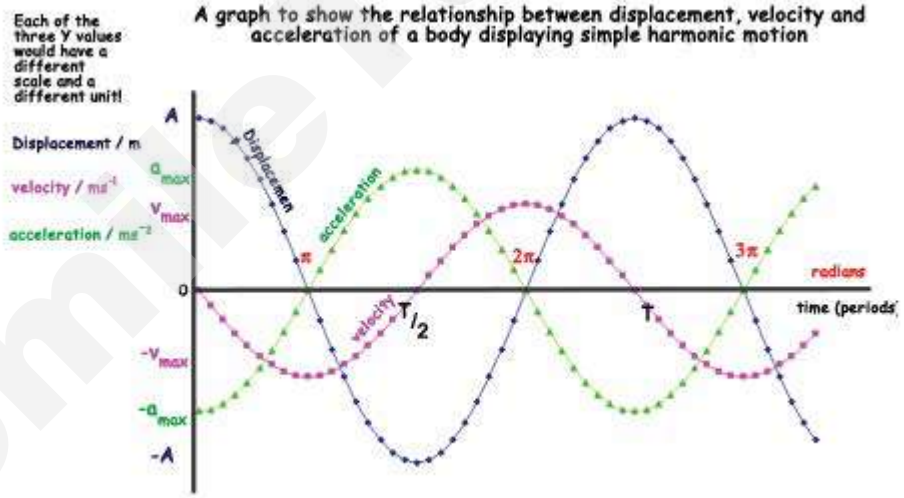
12	**C**	Process 1: Compressed at constant pressure results in lower temperature and hence <u>lower</u> internal energy Process 2: Heated (+Q) and decreasing volume (+W) results in <u>higher</u> internal energy
13	**D**	Since $\frac{3}{2}$ K T = $\frac{1}{2}$ m $(v_{rms})^2$, T is proportional to $(v_{rms})^2$ Since v_{rms} is increased by 1.05 (5%), T is increased by $(1.05)^2$ New temperature = (30 + 273) $(1.05)^2$ = 334 K = 61 °C
14	**C**	**OSCILLATIONS** *acceleration* $a = -(2\pi f)^2 x$ *displacement* $x = A\cos(2\pi f t)$ *speed* $v = \pm 2\pi f\sqrt{A^2 - x^2}$ *maximum speed* $v_{max} = 2\pi f A$ *maximum acceleration* $a_{max} = (2\pi f)^2 A$ *for a mass-spring system* $T = 2\pi\sqrt{\frac{m}{k}}$ *for a simple pendulum* $T = 2\pi\sqrt{\frac{l}{g}}$ • Time period would halve as T = 1/f • Energy is related to v^2 (KE = $^1/_2$ mv^2) - therefore energy would increase by a factor of root 2. • Max velocity would double as v and f are proportional. Acceleration relates to square of frequency so that is incorrect. It would increase by a factor of four.
15	**A**	
16	**D**	I α A^2 and I α $1/r^2$ Therefore, Aα1/r Hence $\frac{A_Q}{A_P} = \frac{r}{(2r)}$ A_Q = 1/2 (8.0)= 4.0 μm
17	**C**	$\lambda = ax / D$ $x_1 = \frac{\lambda_1(D)}{a}$ $x_2 = \frac{\lambda_2(D)}{a}$ For them to coincide,

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		$n_1\lambda_1 = n_2\lambda_2$ where n is the order of the bright fringes Ratio of n_1 / n_2 = 900 / 750 The smallest n_1 such that both n_1 and n_2 are integers is 6. Therefore, Smallest distance is $6x_1 = 6\ (750 \times 10^{-9})(2.0) / (2.0 \times 10^{-3})$ $= 4.5 \times 10^{-3}$ m
18	**B**	Coherence = constant phase difference.
19	**D**	Option D : $v = f\lambda$ By increasing v, λ will be larger, f being constant. The larger λ will be more comparable to the slit width and hence the diffraction will be more significant. Incorrect answers Option A & B: It will not change anything Option C: Increasing the f will reduce the λ, v being constant.
20	**C**	$a = Eq/m = (3.5)\ (1.6 \times 10^{-19}) / 9.11 \times 10^{-31}$ $= 6.15 \times 10^{11}$ $S_x = v_x t$ $t = 0.0002/5500 = 3.64 \times 10^{-8}$ s $v_y = (6.15 \times 10^{11})\ (3.64 \times 10^{-8}) = 22386$ m s^{-1} $v = \sqrt{(22386^2 + 5500^2)} = 2.31 \times 10^4$ m s^{-1}
21	**C**	Electric field strength is proportional to the rate of change in electric potential with respect to distance. Hence maximum electric field strength occurs at the steepest gradient.
22	**C**	R = ρL/A A = ρL/R --- (1) D = M/V = M/LA ⇨ M = DLA --- (2) Substitute (1) into (2): $M = D\rho L^2/R$ M α D ρ (L & R = constant) $M_C/M_A = (D_C/D_A) \times (\rho_C/\rho_A)$ $M_C/M_A = (3D_A/D_A) \times (0.5\ \rho_A/\rho_A)$ $= 3 \times 0.5$ $= 1.50$

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23	**D**	$I = n q A v$ $I = n q (\pi r^2) v$ $v = I / \pi n q r^2$ $v \propto 1/ r^2$ (I, n & q are constants) $v'/v = (r/r')^2$ $v'/v = (r / 0.5 r)^2$ $v' = 4 v$
24	**A**	P.d across variable resistor (R=0) = 0 V P.d across variable resistor (R= 4) = (4/4+6)(6) =2.4 V
25	**B**	Suppose each bulb resistance is R. The initial combined resistance is R/3. Current through each bulb is E/R, ammeter reading is 3(E/R) Power of each bulb is E^2/R After one bulb breaks, The combined resistance is R/2. Current through each bulb is E/R, ammeter reading is 2(E/R) Power of each bulb is E^2/R
26	**D**	Using FLHR, the force is out of the plane $F = (B/2)IL \cos 30^o = 4.0 \cos 30^o = 3.5$ mN
27	**A**	When the small coil experiences increasing flux pointing out of paper, it will induce flux pointing into paper and hence induces a clockwise current. The coil experiences forces pointing into the centre and hence causing it to become smaller.
28	**B**	$V_{rms} = 120 / 2 = 60$ V Mean power = $60^2 / 20 = 180$ W
29	**B**	When the frequency of light is doubled while the intensity remains unchanged, rate of photon incident on metal surface will be halved. This will reduce the photoelectric current by half.
30	**A**	To calculate time t: $N = N_o e^{-(\ln 2/t_{1/2})t}$ $(6.03 \times 10^{11}) = (7.0 \times 10^{11}) e^{-(\ln 2/14)t}$ t = 3.0128 hrs Activity of Original sample after t+27hrs $= (\lambda N_o) e^{-(\ln 2/t_{1/2})t}$ $=(\ln 2/(14*3600) * 7.0 \times 10^{11}) e^{-(\ln 2/14)30.0128}$

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		$=2.1785 \times 10^6$ Bq Activity of new sample K after 27 hours $= 3.62 \times 10^6 - 2.1785 \times 10^6$ $= 1.4415 \times 10^6$ Bq Original activity of K: $A/A_o = (1/2)^{(27/14)}$ $A_o = A / (1/2)^{(27/14)} = 5.4876 \times 10^6$ Bq Hence value of K = $A_o/\lambda = (5.4876 \times 10^6)/(\ln 2/(14*3600)) = 3.99 \times 10^{11}$ **Ans: A**

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2017 9749 JC2 H2 Physics Prelim Paper 2 Solution

1		$\rho = M/V = M/(LBH)$ $\Delta\rho/\rho = \Delta M/M + \Delta L/L + \Delta B/B + \Delta H/H$ $\Delta\rho/2.50 = 0.1/25.0 + 0.01/5.00 + 0.01/2.00 + 0.01/1.00$ $\Delta\rho = 0.0525$ g cm^{-3} $\Delta\rho = 0.05$ g cm^{-3} or 0.06 g cm^{-3} If they leave it as 1 sf or 3 sf here, no marks deducted $(\rho \pm \Delta\rho) = (2.50 \pm 0.05$ or $0.06)$ g cm^{-3}	 **C1** **A1** **A1**
2	**(a)**	Change in momentum = Δp = area under F-t graph $= \frac{1}{2}[80 + 40]\{[150 - 100] \times 10^{-3}\}$ $= 3.00$ kg m s^{-1}	 **C1** **A1**
	(b)	Final momentum = $p_f = p_i + \Delta p$ $= m v_i + \Delta p$ $= (200/1000)(15) + 3.00$ $= 6.00$ kg m s^{-1} $v_f = 30$ m s^{-1}	 **C1** **A1**
3	**(a)**	From point of released of block till point of compression in spring where net force on block is zero or point of maximum speed: Gravitational Potential Energy of block is converted to Kinetic Energy of block and Elastic Potential Energy of spring. From point of compression in spring where net force is zero or point of maximum speed till point of maximum compression: Gravitational Potential Energy of block and Kinetic Energy of block converted to Elastic Potential Energy of spring. **At the point of maximum compression, the Kinetic Energy of block is zero, the Gravitational Potential Energy of block is minimum while the Elastic Potential Energy of Spring is maximum. OR	 **B1** **B1** **B1**

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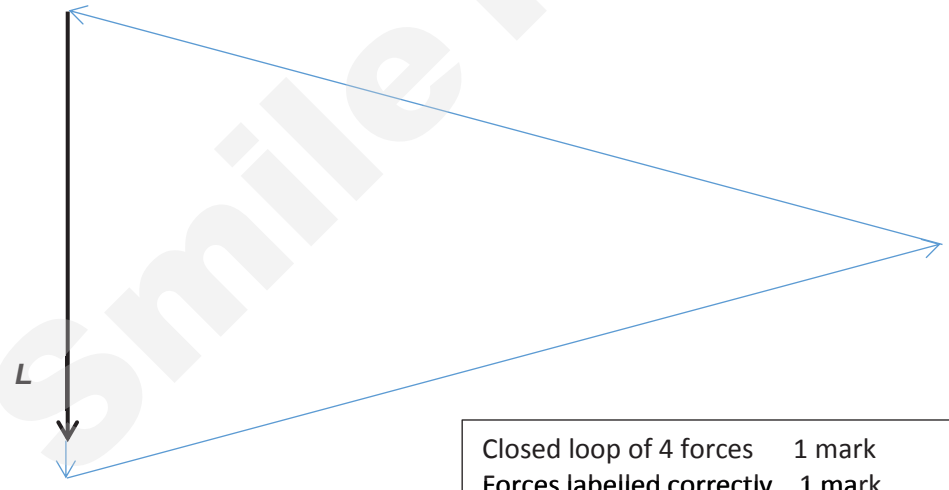
		**From point of release to just before it hits the spring Gravitational Potential Energy of block converted to Kinetic Energy of block.	
	(b)	Initial Position: Where block is released Final Position: Where spring is at its maximum compression Reference Position: Where spring is at its maximum compression By Principle of Conservation of Energy: $GPE_i = EPE_f$ $mg\ h_i = ½\ k\ x^2$ $mg\ (s \sin 30°) = ½\ k\ x^2$ $(12)(9.81)\ (4.3 \sin 30°) = ½\ k\ (1.3)^2$ $k = 300\ N\ m^{-1}$	**M0** **C1** **A1**

4	 Closed loop of 4 forces 1 mark Forces labelled correctly 1 mark Correct arrow directions 1 mark Value of P = 12 000 N (allow 100 N off) If value of P = 11 900 N to 12 100 N → 2 marks If value of P = 11 800 N to 12 200 N → 1 mark If value of P exceeds the range → No mark for accuracy	[5]

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5	**(a)**	Heat exchange between water and ice: Heat gained by ice = heat lost by water $(2.05 \times 10^3)(0.5)(5 - 0) + (3.33 \times 10^5)(0.5) + (4200)(0.5)(T - 0) = (4200)(2.5)(30 - T)$ $T = 11.4\ °C$ Heat exchange between water and steam: Heat gained by water = heat lost by steam $(2.26 \times 10^6)(0.2) + (4200)(0.2)(100 - T') = (4200)(3)(T' - 11.4)$ $T' = 50.6\ °C$	**1** **1** **1** **1**
	(b)	The <u>increase</u> in the internal energy of a system is equal to the sum of heat supplied <u>to</u> the system and the work done <u>on</u> the system.	**1** **1**
	(c)	Since both bubbles are identical, n must be the same. Since both bubbles experience the <u>same water pressure P</u> at the surface, the volume of the ideal gas must be proportional to its temperature. For bubble A, since there is no heat exchange, Q = 0. Therefore $\Delta U = W$. As its volume expands, W and hence <u>ΔU must be negative</u>. Since ΔU is proportional to ΔT, <u>ΔT is negative</u>. So the final temperature is lower than the initial temperature. For bubble B, since it remains in thermal equilibrium with the water, its <u>temperature will increase</u> as the surface temperature will be warmer than the temperature at the bottom. So the final temperature is higher than the initial temperature. Therefore, <u>bubble B will be larger</u> when they reach the surface.	**1** **1** **1**

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6	**(a)**	**(i)**	Formed due to superposition/interference of the incident wave from oscillator and reflected wave from Q. [1] The two waves have the same speed, wavelength/frequency, same amplitude and travel in opposite directions [1]		**1** **1**
		(ii)	There is a 180°/ π radian phase change at Q [1] since it is a fixed end, Hence there is destructive interference between the incident and reflected wave, [1] since they are π radian out of phase. – this mark given only if they are able to explain about the phase change.		**1** **1**
		(iii)	**1.**	½ λ = 0.30 m λ = 0.60 m v = f λ = 120 (0.60) = 72 m s^{-1}	**1** **1**
			2.	Phase difference is zero.	**1**
	(b)		***Light diffracts at the aperture, giving rise to a single slit diffraction pattern at the film or screen. or **θ = λ/b or θ = 1.22λ/b where λ is the wavelength of the light and b is the dimension of the aperture. In order to be able to observe the lights as different entities, the angle between the headlights have to be larger than a critical value, according to Rayleigh criterion. When the car is far away, the angle between the headlights are smaller than the critical θ. When the car is nearer, the angle between the headlights is larger than the critical θ.		**1** **1** **1**

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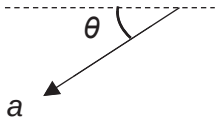
7	**(a)**		Work done per unit positive charge in bringing a point charge from infinity to that point	**1**
	(b)	**(i)**	Neutral point is on the left side of P.	**1**
		(ii)	Electric field strength due to P = electric field strength due to Q $\frac{6\mu}{4\pi\varepsilon_o x^2} = \frac{9\mu}{4\pi\varepsilon_o (50+x)^2}$ x = 223 mm = 0.223 m	**1** **1**
		(iii)	Work done = final EPE – initial EPE $= \frac{(6\mu)(-9\mu)}{4\pi\varepsilon_o}\left(\frac{1}{(223+50)\times10^{-3}} - \frac{1}{50\times10^{-3}}\right)$ = 7.9 J	**1** **1**
	(c)	**(i)**	Electric force = $\frac{(4+1)}{0.1}(0.0025)$ = 0.125 N Weight = (0.005) (9.81) = 0.049 N Net force = $\sqrt{(0.125^2 + 0.049^2)}$ = 0.134 N a = 0.134/0.005 = 27 m s^{-2}	**1** **1**
		(ii)	s = ut + ½ a t^2 s = 0 + ½ (27) $(0.05)^2$ s = 0.034 m = 3.4 cm θ = $\tan^{-1}$ (0.049/0.125) = 21 ° 	**1** **1** **1**

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8	**(a)**		Diagram: Cell, Variable Resistor, Filament Lamp connected in series + Ammeter connected in series to Filament Lamp Voltmeter connected in parallel to Filament Lamp Correct Circuit Diagram Symbols	**B1**
			Procedures: By adjusting resistance of variable resistor to a specific value R, the current I flowing through filament lamp can be obtained from ammeter.	**B1**
			The corresponding potential difference across filament lamp V can be obtained from voltmeter.	**B1**
			Decrease or increase R to obtain another 7 sets of (V, I). Plot the I-V characteristic graph using the 8 sets of (V, I) and draw a best fit curve.	**B1**
	(b)	**(i)**	$I_1 = Q_1/t$ $= [(N_1)/t] \times e$ $= (2.58 \times 10^{16})\ (1.60 \times 10^{-19})$ $= 4.13 \times 10^{-3}$ A	**M0** **C1** **A1**
		(ii)	$I_T = I_1 + I_2$ $Q_2/t = I_T - I_1$ $[(N_2)/t] \times p = I_T - I_1$ $N_2)/t = (I_T - I_1)/p$ $= \{(8.16 - 4.13) \times 10{-}3\}/(3.2 \times 10^{-19})$ $= 1.26 \times 10^{16}\ s^{-1}$	**M0** **C1** **A1**

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9	**(a)**	Power = $\frac{N_{photons}}{t}\left(\frac{hc}{\lambda}\right)$ $\frac{N_{photons}}{t} = \frac{1.2(530\times10^{-9})}{(hc)}$ $\frac{N_{photons}}{t}$ = 3.2 × 10^{18} / s	**1** **1**
	(b)	Energy of each photon = $\frac{hc}{530\times10^{-9}}$ = 2.35 eV Since energy of photon is greater than work function, photoelectrons will be emitted.	**1**
	(c)	$p = \frac{h}{530\times10^{-9}}$ = 1.25 × 10^{-27} Pressure = $\frac{Force}{area} = \frac{rate\ of\ change\ in\ momentum}{area}$ = $\frac{(1.25\times10^{-27})(3.2\times10^{18})}{3.8\times10^{-6}}$ = 1.1 × 10^{-3} Pa	**1** **1**

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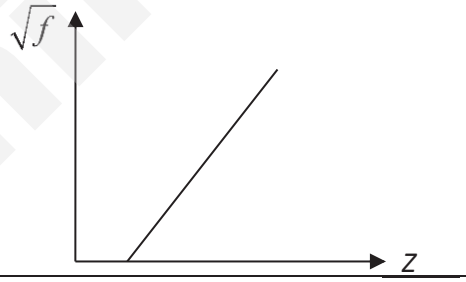
10	**(a)**	**(i)**	When an electron collides with one of the target atoms, it may lose an amount of energy that corresponds to the energy of an X-ray photon. The electron may continue to lose energy in a series of collisions with other atoms, thereby giving off X-ray photons of different energies. Since different X-ray photons correspond to different wavelengths, the continuous spectrum is thus formed.	B1 B1
		(ii)	Min wavelength corresponds to max frequency and thus energy of photons. Hence max loss of energy due to most energetic (not important) electron losing all its KE to a single photon.	B1
	(b)	**(i)**	An empirical relation is one which is guided by experimental observations rather than by theory.	B1
		(ii)	Units of a = s^{-1} Units of b = dimensionless	B1
		(iii)	A material with a large atomic number will result in a braking radiation of higher intensity, or Elements of small atomic number will not result in large enough energy loss of the incoming electrons via braking radiation and so photons produced will not be X rays	B1
	(c)	**(i)**	$f = a(Z-b)^2$ $\sqrt{f} = \sqrt{a}(Z-b) = \sqrt{a}Z - \sqrt{a}b$  	M1 A1
		(ii)	As the atomic number (Z) of elements increases, the frequency (f) of the emitted x-rays will increase. Since energy of x-rays is proportional to its frequency (E = hf), the energy of the x-rays will increase with increasing atomic number.	B1 B1
	(d)	**(i)**	$E_k = -\frac{13.6 \times 74^2}{1^2}$ eV $= -1.19 \times 10^{-14}$ J	M1 A1

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		(ii)	When an electron from the K shell is displaced, for electron in shell M: $Z_{eff,3} = 74 - 1 - 8 = 65$ $E_M = -\frac{13.6 \times 65^2}{3^2}$ eV $= -1.02 \times 10^{-15}$ J $\Delta E = \left\lvert E_k - E_M \right\rvert$ $= \lvert(-1.19 \times 10^{-14}) - (-1.02 \times 10^{-15})\rvert$ $= 1.09 \times 10^{-14}$ J	B1 M1 A1 M1 A1
	(e)	**(i)**	Left peak : K_β Right peak : K_α	B1
		(ii)	Since the L shell is closer than the M shell to the K shell, the <u>closer transition</u> is more likely to occur. Intensity depends on the number of photons emitted per unit time and hence it is dependent on the probability of the transition. or Although the transition K_α results in the emission of a x-ray photon with lower energy, the probability of this transition happening is higher than that of transition K_β.This higher probability mitigates the lower energy of each x-ray photon emitted, resulting in higher intensity of x-ray with this wavelength being produced.	B1 B1

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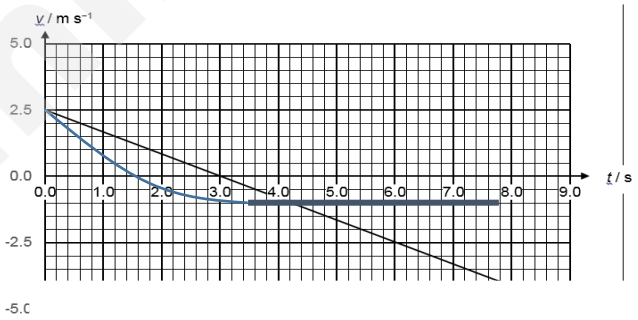
1	**(a)**		acceleration = gradient of the graph $= \frac{-2.5-2.5}{6.0-0}$ $= -0.83\ \text{m s}^{-2}$	**1**
		Marker's comment		
	(b)		$v^2 = u^2 + 2as$ $= [5.0\ (\sin 30)]^2 + 2\ (-0.83)(-1.5)$ $v = 2.96\ \text{m s}^{-1}$	**1** **1**
		Marker's comment		
	(c)		The area between t = 6.02 s to point where v = calculated value of (b) 1 mark for correct starting time 1 mark for the ending time which corresponds to value of (b)	 **1** **1**
		Marker's comment		
	(d)		$v_x = 5.0 \cos 30 = 4.33\ \text{m s}^{-1}$ Hence the point is at the position where the vertical velocity is also 4.33 m s^{-1} (t will be at 8.2 s) Correct point on the graph	**1** **1** **1**
		Marker's comment		
	(f)		 Correct curvature [1] The object may not have reached terminal velocity Max height is reached at a shorter time [1]	**1** **1**

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2	(a)		The principle of conservation of momentum states that total momentum in a closed system remains constant if the net external force acting on the bodies is zero.	B1 B1
		Marker's comment		
	(b)	(i)	It means that the point of impact is on the straight line connecting the centre of mass of the two objects. Or centre of mass of the two objects approaches each other in a straight line.	B1
		(ii)	Rightwards as positive: $\Sigma p_i = \Sigma p_f$ $(0.0200)(8.0) + (0.0100)(5.0) = (0.0200)(-2.0) + (0.0100)\ v$ $v = 25\ m\ s^{-1}$	 M0 C1 A1
		Marker's comment		
		(iii)	Rightwards	B1
		Marker's comment		
		(iv)	On 0.0100 kg object: $\Sigma F = \Delta p/\Delta t$ $= m\ (v_f - v_i)/\ \Delta t$ $= (0.0100)\ [(+25) - (5.0)]/0.120$ $= 1.67\ N$ Alternatively: On 0.0200 kg object: $\Sigma F = \Delta p/\Delta t$ $= m\ (vf - vi)/\ \Delta t$ $= (0.0200)\ [(-2) - (+8)]/0.120$ $= -\ 1.67\ N$ By Newton's Third Law, ΣF on 0.0100 kg object = ΣF on 0.0200 kg object = 1.67 N	 M0 C1 A1 M0 C1 A1
		Marker's comment		
		(v)	If both objects stop at the same instant, the total momentum of both objects is zero at that instant. However, before the collision, the total momentum of both objects was non-zero. This violates the principle of conservation of momentum which specify that the total momentum remains non-zero.	B1 B1

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		Marker's comment		
3	**(a)**		The gradient of the graph is constant. Since gravitational field strength g = -dϕ / dr, the field strength is constant.	**1** **1**
		Marker's comment		
	(b)		$\phi_{100\ km}$ = − 61.52 MJ kg^{-1} $\phi_{10\ km}$ = − 62.4 MJ kg^{-1} [1 mark for reading off correctly] Work done = change in GPE = $m(\phi_{100\ km} - \phi_{10\ km})$ = 4200 (− 61.52 + 62.4) × 10^6 = 3.7 × 10^9 J [1 mark for final answer. Deduct 1 mark if candidate did not read in MJ kg^{-1}]	**1** **1**
		Marker's comment		
	(c)	**(i)**	$\omega = 2\pi / T$ T = 5236 s = 5200 s	 **1**
		Marker's comment		
		(ii)	$\sum F = mr\omega^2$ $m(9.7) = m(R_E + 100 \times 10^3)\ \omega^2$ R_E = 6.6 × 10^6 m	 **1** **1**
		Marker's comment		
	(d)		The mass of moon is smaller than mass of Earth The gravitational field strength experienced by moon shuttle will be smaller. [It will be incorrect to mention that the gravitational force will be larger/smaller or centripetal force will be larger/smaller since the mass of the moon shuttle is different.] The period will be longer.	**1** **1** **1**
		Marker's comment		
4	**(a)**	**(i)**	$\omega = 2\ \pi\ f$	**1**
		(ii)	Either "acceleration and displacement are always in opposite direction" Or "acceleration is always directed towards the equilibrium"	 **1**
		Marker's comment		

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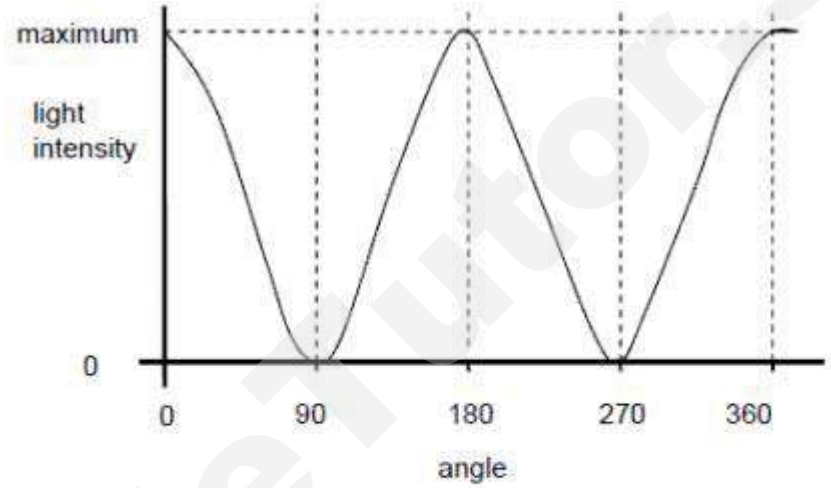
	(b)	**(i)**	Forces in spring are *k(e+x)* and *k(e-x)* Resultant force = restoring force *F = k(e+x) – k(e-x)* *F = 2kx*	**1** **1**
		(ii)	F= ma a = 2kx/m |a|= $\omega^2 x$ *hence* $\omega^2 = 2k/x$	 **1** **1**
		Marker's comment		
	(c)	**(i)**	 max 0, 180, 360 + min 90, 270 **(1)** **and** line reaches same minimum and maximum every time and reasonable shape **(1)**	**2**
		(ii)	LCD screens, camera lenses, 3-D glasses, Polarised sunglasses	**1**
		(iii)	For longitudinal wave, the direction of oscillations are parallel to the direction of wave propagation, hence the transmission axis will have no effect and no polarisation can be observed.	**1**
		Marker's comment		
5	**(a)**		Potential difference between two points of a circuit **is the amount of electrical energy converted per unit charge into** other forms of **energy** when the charge moved from one point to the other. Electromotive force of a source is defined as the **energy converted per unit charge from other forms of energy into electrical energy** when the charge is driven through the source round a complete circuit.	**1** **1**
			Marker's comment	

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	(b)		Calculate safe maximum current 500 Ω : current = $\sqrt{\frac{P}{R}} = \sqrt{\frac{0.8}{500}}$ = 0.040 A 2 x 0.040 = 0.080 A 320 Ω : current = $\sqrt{\frac{0.8}{320}} = 0.050$ A 2 marks for calculating max current for both types of resistors. The 320 Ω resistor will be damaged first. Maximum current in circuit = 0.050 A 1 mark for recognizing the maximum current or the resistor which will be damaged first. Maximum safe p.d = 0.050 (320 + 250)= 28.5 V 1 mark for determining the maximum safe potential difference.	**1** **1** **1** **1**
			Marker's comment	
	(c)	**(i)**	Lamp K. When switches B, C, D, E are closed and switch A open, the reading should be 45 Ω. But the reading measured is 0.2 Ω.	**1** **1**
			Marker's comment	
		(ii)	The lamp is short-circuited or any other possible reason which could cause the resistance of the lamp to be reduced to near zero. Do not accept that the lamp is fused because if the lamp is fused, the resistance should be infinite (open circuit).	**1**
		Marker's comment		
		(iii)	The resistance meter has its own internal resistance of 1.4 x 10^7 when operated. (This resistance is connected in parallel to the rest of circuit. Hence when the rest of the circuit to be measured has infinite resistance, the effective resistance is its own internal resistance.) Do not accept resistance meter is non-ideal or that the resistance meter can only give a maximum reading of this value. These answers are too generic. Student should explain more clearly.	**1**
		Marker's comment		

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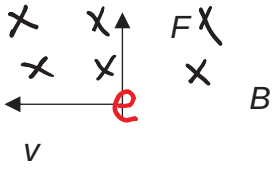
6	(a)		The magnetic flux density of a magnetic field is defined as the force exerted on a unit length of conductor carrying a unit current placed at right angles to the field.	1
	(b)		$F = 1.6 \times 10^{-19} Bv$ Should use either "e" (elementary charge) or 1.6×10^{-19} for the charge instead of the generic *q*.  1 mark for *F, v , B* perpendicular to each other. 1 mark for correct direction of *F* using FLHR on electron	1 1 1
		Marker's comment		
	(c)	(i)	As a result of the magnetic force acting on the electrons, there will be a build-up of charges at the sides of the conductors, producing a measurable voltage, v between the two sides of the conductor.	1
		Marker's comment		
		(ii)	ADHE	1
		Marker's comment		
		(iii)	Since $I = neAv$ Hence $v = I/neA$ $(A = wd)$ At equilibrium condition, the magnetic force is balanced by an electric force. $F_B = F_E$ $Bqv = qE$ $(E = V/w)$ $B(I/neA) = V/w$ $V = \frac{IB}{ned}$ Note: V is hall p.d, v is drift velocity.	1 1 1
		Marker's comment		
	(d)		For semi-conductors, the charge density *n*, is much less than for metals and hence Hall voltage or p.d is larger and easier to measure.	1
		Marker's comment		
7	(a)	The direction of the induced emf is such that the current which it causes to flow (or would flow in a closed circuit) opposes the change in magnetic flux which is producing it.		1
		Marker's comment		

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	(b)	**(i)**	Rod AB: end A has higher potential Rod CD: end D has higher potential	**1** **1**
		Marker's comment		
		(ii)	Induced e.m.f. in rod AB = B l v = (0.65) (0.12) (2) = 0.16 V Induced e.m.f. in rod CD = (0.65) (0.12) (3) = 0.23 V	**1** **1**
		Marker's comment		
		(iii)	Induced current = Total e.m.f. / total resistance = (0.16 + 0.23) / (8 + 10) = 0.022 A	**1** **1**
		Marker's comment		
		(iv)	Total power dissipated = I V = (0.022) (0.23 + 0.16) = 0.0086 W	**1** **1**
		Marker's comment		
		(v)	External force = Induced magnetic force on rod AB / CD = B I L = (0.65) (0.022) (0.12) = 0.00172 N Rate of work done by external force on rod AB = F v = (0.00172) (2) = 0.0034 W Rate of work done by external force on rod CD = (0.00172) (3) = 0.0052 W Total rate of work done by external force on both rods = 0.0034 + 0.0052 = 0.0086 W	**1** **1** **1**

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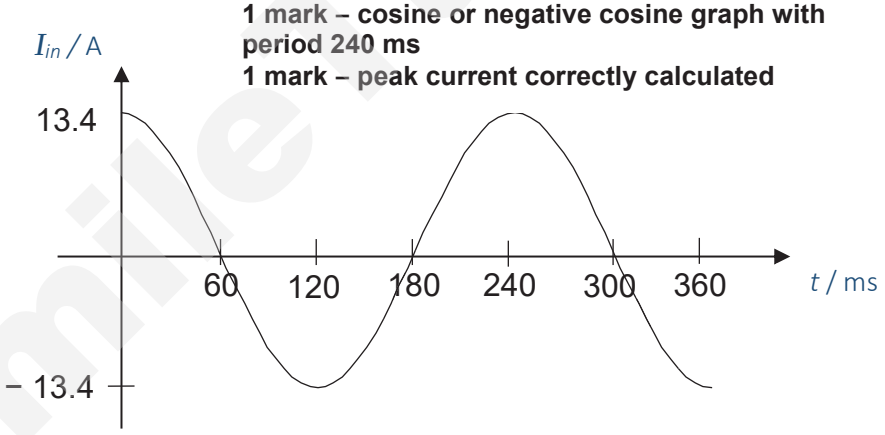
			Since rate of work done is the same as power dissipated, energy is conserved.	
		Marker's comment		
	(c)	Effective direct current that produces the same heating effect as the alternating current.		**1**
		Marker's comment		
	(d)	**(i)**	Peak output power = peak input power = 1.8 W Peak output power = V_o^2 / R V_o^2 = (1.8) (4) V_o = 2.7 V Output V_{rms} = 1.9 V	 **1** **1**
		Marker's comment		
		(ii)	Input V_{rms} = 1.9 / 20 = 0.095 V Input I_{rms} = 0.9 / 0.095 = 9.5 A	**1** **1**
		Marker's comment		
		(iii)	**1 mark – cosine or negative cosine graph with period 240 ms** **1 mark – peak current correctly calculated**  	**2**
		Marker's comment		
		(iv)	I = 13.4 cos 26 t or − 13.4 cos 26 t	**1**
		Marker's comment		
8	**(a)**	**(i)**	The half-life of a radioactive isotope is the average time taken for half the number of atoms in the isotope to decay.	**1**
		Marker's comment		
		(ii)	The decay constant is defined as the probability of decay per unit time of atoms of a radionuclide.	**1**
		Marker's comment		

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		(iii)	It is impossible to predict exactly which nucleus will decay next and thus the decays appear randomly throughout the sample.		**1**
		Marker's comment			
	(b)	**(i)**	Mass difference in the beta decay, Δm = (89.90774 – 89.90715 – 0.0005485) = 4.0000×10^{-5} u Assuming that the energy released are in the form of kinetic energy for the daughter particles, Conservation of energy: $$\frac{1}{2}m_Y {v_Y}^2 + \frac{1}{2}m_\beta {v_\beta}^2 = \Delta m c^2$$ Conservation of momentum: $$m_Y v_Y = m_\beta v_\beta$$ Solving, $v_\beta = \sqrt{\frac{2\Delta m c^2}{\frac{m_\beta{}^2}{m_Y}+m_\beta}}$ = 1.15×10^8 m s^{-1} v_Y = 699 m s^{-1} v_β = 1.1×10^8 m s^{-1}		**1** **1** **1** **1**
		Marker's comment			
		(ii)	The half-life of strontium-90 is very long (28.3 yrs). In order to have accurate measurements of half-life, measurements either have to be taken for a very long period of time (years) or to use a large quantity of the sample which would pose health hazard. Since daughter nucleus Yttrium also undergo decay, it is impossible to know an emitted beta particle is due to the decay of which nucleus.		**M1** **A1** **B1**
		Marker's comment			
		(iii)	Need to account for the background radiation, as well as the additional beta decay due to the daughter nucleus Yttrium. Keeping GM tube at a fixed distance from the source.		**1** **1**
		Marker's comment			
		(iv)	Unborn children are more vulnerable to radiation as the cells are rapidly dividing. If the DNA of the cells is affected at this stage, the subsequent cells that develop from these cells will be affected as well. The beta source is dangerous when outside the body – because they can penetrate the skin and damage the cells inside.		**1** **1** **1**
		Marker's comment			
		(v)	1.	Into the page	**1**
		Marker's comment			
			2.	The beta particles ionises the gas particles along its path.	**M0**

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				This causes it to lose energy and so lose speed. Since radius is proportional to velocity (mv/Bq), the radius continually decreases with its energy/speed.	**A1** **M1**
		Marker's comment			
			3.	Estimated radius 30-40mm $Bqv = mv^2/r$ $\therefore v = (3.0 \times 10^{-4})(1.6 \times 10^{-19})(0.030) / (9.11 \times 10^{-31})$ $= 1.58 \times 10^6$ m s^{-1}	**M1** **A1**
		Marker's comment			

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2017 9749 JC2 H2 Physics Prelim Paper 4 Solution

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1 (a) (ii)</td><td>MMO
y_0 recorded to the correct precision with correct unit. (E.g. 4 d.p. in metres or 2 d.p. in centimetres.)</td><td>1</td></tr>
<tr><td>1 (a) (iv)</td><td>MMO
y recorded to the correct precision with correct unit. (E.g. 4 d.p. in metres or 2 d.p. in centimetres.)</td><td>1</td></tr>
<tr><td>1 (a) (vi)</td><td>ACE
Correct calculation of $(y - y_0)$. $(y - y_0)$ recorded to the correct precision with correct unit. (E.g. 3 d.p. in metres or 1 d.p. in centimetres.)</td><td>1</td></tr>
<tr><td>1 (a) (vii)</td><td>ACE
Absolute uncertainty of 2 mm to 4 mm.
Value given as 1 or 2 s.f. with % sign.</td><td>1</td></tr>
<tr><td>1 (b) (iii)</td><td>ACE
Correct calculation of $(y - y_0)$. Value must be smaller than value in (a)(vi).

$(y - y_0)$ recorded to the correct precision with correct unit. (E.g. 3 d.p. in metres or 1 d.p. in centimetres.)</td><td>1

1</td></tr>
<tr><td>1 (c) (i)</td><td>ACE
Award 2 marks if candidate show evidence of at least 2 sets of positions of masses with deflection $(y - y_0)$ recorded when the mass is placed individually in a table.

Award 1 mark if candidate show evidence of only 1 set of positions of masses with deflection $(y - y_0)$ recorded when the mass is placed individually in a table.

E.g.
<table>
<tr><th>M1 position / cm</th><th>$y - y_0$ when only M1 is placed / cm</th><th>M2 position / cm</th><th>$y - y_0$ when only M2 is placed / cm</th><th>Expected $y - y_0$ when both masses are put together/ cm</th><th>Measured $y - y_0$ when both masses are put together / cm</th></tr>
<tr><td>90.0</td><td></td><td>50.0</td><td></td><td></td><td></td></tr>
<tr><td>80.0</td><td></td><td>50.0</td><td></td><td></td><td></td></tr>
</table>
Clarity of the record of the observations. Mark given only if the table headings are labelled clearly together with the units and correct d.p.</td><td>Max 2

1</td></tr>
<tr><td>1 (c) (ii)</td><td>ACE
Correct calculation of the percentage difference by $\frac{Measured - Expected}{Can\ be\ either\ of\ the\ values} \times 100\,\%$. [The mark can be given if value is found in the table in (c)(i).

Correct conclusion drawn comparing the percentage difference with 10% error.</td><td>1

1</td></tr>
</table>

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1(d)(i)	1. The ruler clamped to the retort stand may not be vertical when taking the *y* measurements. 2. There is a gap between the ruler with mass and the vertical ruler, hence there will be parallax error when taking the y reading. 3. Masses were not put at the same position on the rule as in a previous deflection measurement. 4. The elastic property of the rule may change if the masses are place on the rule for a long time. (Give BOD to students with elastic limit of the ruler is exceeded) 5. The ruler kept moving even after waiting for a significantly long time. (However for this error, there is no appropriate improvement)	**1**
1(d)(ii)	1. Use a spirit level against the ruler and adjust the ruler such that the bubble in the spirit level is within the specified lines before taking the *y* measurements. 1. Use a plumb line attached to the retort stand and ensure that the ruler is always parallel to the plumb line before taking the *y* measurements. 1. Measure at 2 positions of the ruler and ensure that the distance between the ruler from the vertical body of the retort stand at these positions is the same before taking the *y* measurements. 2. Use a set square to place at the bottom of ruler with mass to help in reading off from the vertical ruler. 2. Use a marker that is attached parallel to the short edge of rule A pointing towards rule B. 3. Use a pen to mark out the positions of the masses when placed on the rule. 3. Use a string to hang the masses instead of putting them on top of the ruler. 4. Remove the masses immediately after the measurement is taken. (Do not allow changing to a new ruler every time after doing the measurement)	**1**
	Total	**13**

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Question	Answer	Marks
2 (a) (i)	**MMO** *x* recorded to the correct precision with correct unit. (E.g. 3 d.p. in metres or 1 d.p. in centimetres.)	1
2 (a) (iv)	**MMO** Make a marking at the centre of the wooden block, measure using a half-metre rule the distance from the edge of the rod to the marking and adjust to ensure that the distance equals to *x*. Measure the width of the block. Ensure that the distance from edge of the rod to the edge of the block is x minus half of the width of the block.	1
2 (b) (ii)	**MMO** Evidence of repeated reading + correct precision + correct unit [Evidence can be obtained from the table] Number of oscillations n must be taken such that n*T* is more than 10 s.	1 1
2 (c) (i)	**MMO** • Award 1 marks only if candidate has successfully collected all 5 sets of data (*x*, *T*) without assistance/intervention. **PDO** Clear heading with correct units in the headings of the table. The value of N (no. of oscillations) must be shown. (Allow words in the headings) **PDO** All values of raw data are recorded to the correct precision. Eg *x*/m (3 decimal places), *t*/s (1 decimal place). **PDO** For each value of calculated quantity, the number of significant figures should be the same as the number of significant figures in the raw data. Eg *T*/s (3 or 4 significant figures) [	1 1 1 1
2 (c) (ii)	**ACE** Value of *x* given can be the x where *T* is minimum or it can be in the interval just before the mimimum *T* (to highlight and discuss) or it can be in the interval just after the minimum *T* *x* recorded with the correct unit. (Precision is not emphasised here since it is an estimate)	1
2 (c) (iii)	**ACE** Since there is a decreasing trend of *T* as x increases to ____ (the *x* value when *T* is minimum) and an increasing trend of *T* for x greater than _____, the value of x is minimum point or there exists a minimum point in the interval between the x = ____ and the next x value.	1
	Total	**10**

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Question	Answer	Marks
3 (a) (iii)	**MMO** I_1 and I_2 recorded to the correct precision with correct unit. (E.g. 1 or 2 d.p. in mA)	**1**
3 (b)	**MMO** • Award 2 marks if candidate has successfully collected 6 or more sets of data (*R*, I_1, I_2) (including the set obtained in previous part) without assistance/intervention. • Award 1 mark if candidate has successfully collected 5 sets of data (*R*, I_1, I_2) without assistance/intervention. • Award zero mark if candidate has successfully collected 4 or fewer sets of data (*R*, I_1, I_2) without assistance/intervention. • Deduct 1 mark if candidate requires some assistance/intervention but has been able to do most the work independently. • Deduct 2 marks if candidate has been unable to collect data without assistance/intervention. **PDO** Each column heading (raw data and calculated/derived quantities) must contain a quantity and unit. Eg *R*/Ω, I_1/mA, I_2/mA, $\frac{I_1}{I_2}$ (no units). **PDO** For each value of calculated quantity, the number of significant figures should be the same as the number of significant figures in the raw data. E.g. $\frac{I_1}{I_2}$ follows least significant figures of I_1 and I_2. **ACE** Derived quantities $\frac{I_1}{I_2}$ calculated correctly. Allow a maximum of 1 slip for each derived quantity.	**2** **Minimum Mark = 0** **1** **1** **1**
3 (c) (i)	**PDO (Graph)** Sensible scales must be used. Awkward scales (eg. 3:10) are not allowed. Scales must be chosen so that plotted points occupy at least half the graph grid in both x and y directions. Axes must be labelled with the quantity/unit which is being plotted. **PDO (Graph)** All observations must be plotted accurately within of half a small square. **PDO (Graph)** Assessed best fit line. Straight line of best fit – judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.	**1** **1** **1**
3 (c) (ii)	**ACE** Gradient – the hypotenuse of the Δ must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Gradient coordinates substituted correctly. Gradient calculated correctly. No unit for gradient. (Ignore unit given by candidates)	**1** **1**

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	ACE *y*-intercept must be read off to the nearest half small square or calculated correctly from $y = mx + c$ using a point on the line. (Ignore unit given by candidates)	
3 (d)(ii)	**ACE** *P* determined correctly from the value of gradient with correct unit. (E.g. Ω^{-1}) *Q* determined correctly from the y-intercept with no unit.	**1** **1**
3 (e)	**ACE** The length of the wire M measured using the metre rule is _____ m. Hence *R*' calculated for wire M is _____ Ω m^{-1}. (1/P $\times$ length) Correct choice of swg of wire M.	**1** **1** **1**
3 (f)	**ACE** Percentage difference between theoretical Q and Q from (d) = $\frac{Q \text{ from (d)} - \text{Theoretical } Q \text{ from (f)}}{\text{Either of the } Q \text{ value}}$. Since the percentage difference is < 10%, it supports. Since the percentage difference is > 10%, it does not support.	**1** **1**
3 (g) (i)	**ACE** Length of M increases → Resistance of M increases → P will decrease → gradient will be less → graph is less steep. Q will also decrease → y-intercept will also decrease. Graph drawn is less steep with a smaller y-intercept.	**1**
3 (g) (ii)	**ACE** When the length is reduced, the resistance of the wires is reduced. With swg which has a large diameter, the resistance wires may be reduced to a value such that the current passing resistor Y will be too large and the resistor may melt due to overheating.	**1**
	Total =	**20**

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Question	Answer		Marks
4	**Defining the problem (2 marks)**		
	P1	Vary *v* and measure *d*, or *v* is the independent variable and *d* is the dependent variable	**1**
	P2	Keep the mass/type of pellet and adsorbent material constant Keep the distance between rifle and absorbent material constant Award one mark for any of the above.	**1**
	Methods of data collection (5 marks)		
	M1	Diagram showing the rifle, appropriate position of absorbent material, light gates (if any)	**1**
	M2	Place aluminium foil at fixed position from rifle, vary the thickness of the aluminium to vary the speed of the pellet before reaching the material.	**1**
	M3 M4	If light gates are used, three marking points 1. Measure distance *d* between the two light gates using a metre rule 2. Record the time taken *t* from the data-logger 3. Calculate the speed v of the pellet using the formula v = d/t [2 marks. Deduct 1 mark for missing every missing point.] If speedometer is used, only 1 marking point 1. Obtain the speed *v* from the speedometer. [Only 1 mark. The other mark is placed under additional details] Note: Do not award marks for stopwatch methods. Students need to be aware that the pellet speed will be high and stopwatch method is highly unreliable in measuring high speed.	**2**
	M4	Appropriate method to determine depth that pellet is embedded e.g. using tail of Vernier callipers, or pointer (needle) inserted into the depth and make marking, remove it and measure against ruler.	**1**
	Method of analysis (2 marks)		
	A1	Propose a relationship of $d = kv^n$	**1**
	A2	Plot a graph of log d against log v. If a straight line is obtained, the relationship is correct. The value of n = gradient and log k = y-intercept.	**1**
	Additional details (2 marks) or (3 marks if speedometer is used)		**2**
	1	The position of the light gates must be near to the absorbent material.	
	2	The distance between the mounted rifles cannot be too far from the absorbent material, otherwise, the pellet will move in parabolic path and may not hit the material.	
	3	Preliminary experiment to determine suitable distance between the rifle and the material.	
	4	Repeat experiment to ensure that the speed remains can be reproduced and determine an average of d.	
	Safety considerations (1 mark)		
	S1	Precautions linked to high speed pellet and recoil of rifle	**1**

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