Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9646/01**

Paper 1 Multiple Choice 30 Aug 2016

1 hour 15 minutes

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 **forty** 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.

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}

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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

1 Which estimate is realistic?

A The order of magnitude of the frequency of bluetooth signal is 10^9 Hz.
B The acceleration of the Singapore MRT when moving off from a station is 10 m s^{-2}.
C The density of air at atmospheric pressure is 1.2 g cm^{-3}.
D The order of magnitude of pressure of air in a car tyre is 10^3 Pa.

2 When computing systematic and random errors, the following pairs of properties of errors in an experimental measurement may be obtained:

X_1: error can possibly be eliminated
X_2: error cannot possibly be eliminated
Y_1: error is of constant sign and magnitude
Y_2: error is of varying sign and magnitude
Z_1: error can be reduced by averaging repeated measurements
Z_2: error cannot be reduced by averaging repeated measurements

Which properties apply to the **random errors**?

A X_1, Y_1, Z_2
B X_1, Y_2, Z_2
C X_2, Y_2, Z_1
D X_2, Y_1, Z_1

3 In an experiment to determine the thickness of the glass of a boiling tube, the following readings were taken using vernier calipers.

Internal diameter, d_1 = (2.064 $\pm$ 0.004) cm
External diameter, d_2 = (2.560 $\pm$ 0.004) cm

The uncertainty in the thickness of the glass is

A $\pm$ 0.002 cm
B $\pm$ 0.004 cm
C $\pm$ 0.008 cm
D $\pm$ 0.016 cm

4 A ball is dropped from a height of 20 m and rebounds with a speed which is $\frac{3}{4}$ of the speed with which it hits the ground.

What is the time interval between the first and second bounces?
(Assume that g is $10\ m\ s^{-2}$)

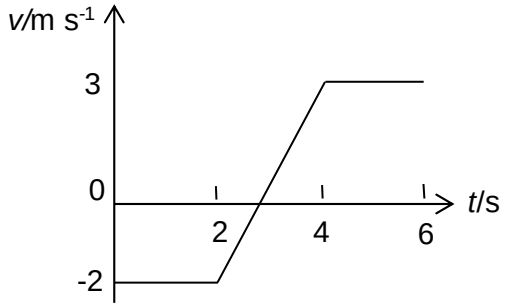
A 1.5 s **B** 2.5 s **C** 3.0 s **D** 4.0 s

5 Two stones, X and Y, of different mass are dropped from the top of a cliff. Stone Y is dropped a short time after stone X. Air resistance is negligible.

Whilst the stones are falling, the distance between them will

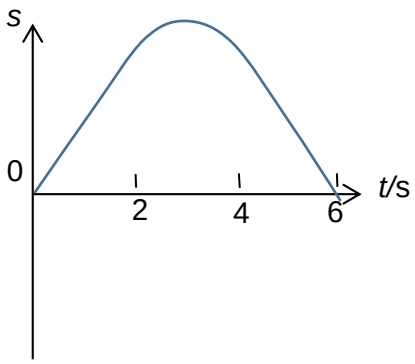
A Decrease if the mass of Y is greater than the mass of X
B Increase if the mass of X is greater than the mass of Y
C Decrease whether the mass of X is greater or less than the mass of Y
D Increase whether the mass of X is greater or less than the mass of Y

6 The figure below shows the velocity vs time (v - t) graph of an object. At time t = 0 s, the object's displacement from the origin is 0 m.

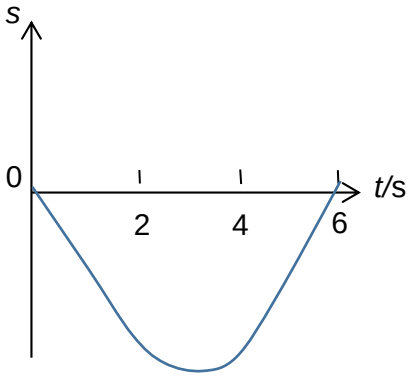


Which of the following best shows the corresponding displacement versus time (s - t) graph of the object?

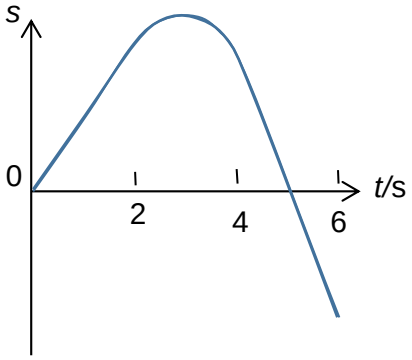
A



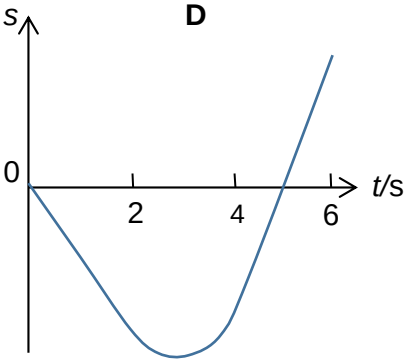
B



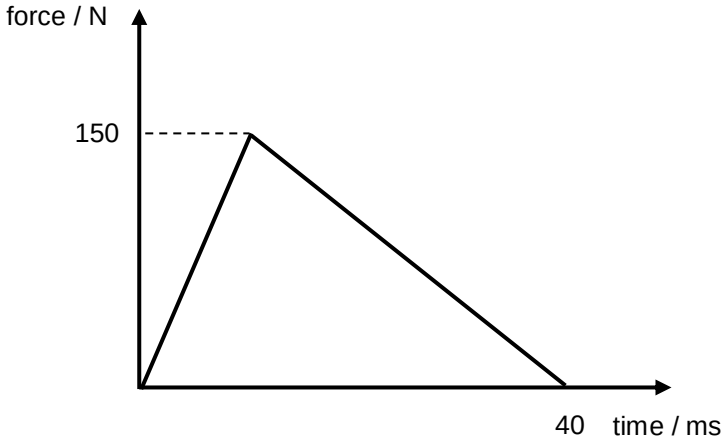
C



D



7 When a player serves a tennis ball of mass 0.060 kg, it is given an impulse of the form shown by the diagram.



Assuming the tennis ball was moving normally towards the racket at 5.0 m s^{-1} just before the racket hits it, its speed, in m s^{-1}, when it leaves the racket is

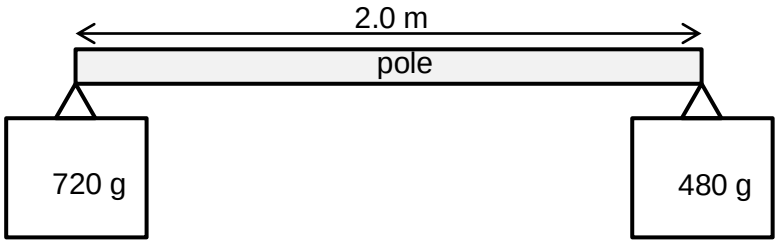
A 45 **B** 50 **C** 55 **D** 95

8 A car of mass 1000 kg moving at 5.0 m s^{-1} on an icy road collides with another car of mass 600 kg moving at 3.0 m s^{-1} in the opposite direction. After the collision, the lighter car moves off at 2.5 m s^{-1} in the initial direction of the heavier car.

What is the speed of the heavier car after the collision?

A 0.5 m s^{-1} **B** 1.7 m s^{-1} **C** 5.3 m s^{-1} **D** 8.3 m s^{-1}

9 A pole of length 2.0 m has non-uniform composition, so that the centre of gravity is not at its geometrical centre. The pole is laid on supports across two weighing balances as shown in the diagram below. The balances (previously set to zero) recorded readings of 720 g and 480 g respectively.



Where is the centre of gravity of the pole with respect to its geometrical centre?

A $\frac{1}{5}$ metre to the left

B $\frac{1}{5}$ metre to the right

C $\frac{1}{3}$ metre to the left

D $\frac{1}{3}$ metre to the right

10 A force of 1000 N is needed to lift the hook of a crane at a steady velocity. The hook is then used to lift a load of mass 1000 kg at a velocity of 0.50 m s^{-1}.

How much of the power developed, in kW, by the motor of the crane is used in lifting the load?

A 4.9 **B** 5.0 **C** 5.4 **D** 5.5

11 An object, immersed in a liquid in a tank, experiences an upthrust.

What is the physical reason for this upthrust?

A The value of the acceleration due to free fall in the liquid increases with depth
B The pressure in the liquid increases with depth
C The density of the body differs from that of the liquid
D The density of the liquid increases with depth

12 A point mass moves through a circular arc of length *s* and radius *r* in time *t*.

What is the angular velocity about the center of the circle?

A $\frac{s}{rt}$ **B** $\frac{r}{st}$ **C** $\frac{2\pi}{st}$ **D** $\frac{2\pi t}{r}$

13 A small spherical planet has radius *R* = 2000 m and has no atmosphere. The acceleration due to gravity on the surface of this planet is 2.0 m s^{-2}.

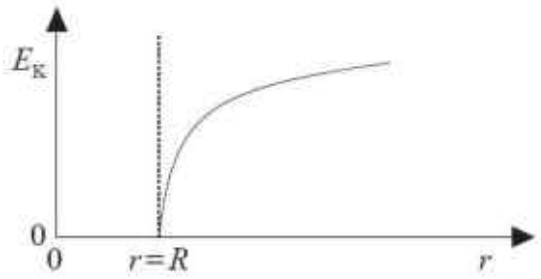
At an altitude of 3000 m above the surface of the planet the magnitude of the gravitational field strength is

A 1.3 N kg^{-1} **B** 0.89 N kg^{-1} **C** 0.80 N kg^{-1} **D** 0.32 N kg^{-1}

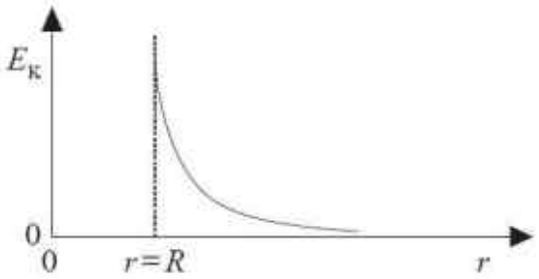
14 The kinetic energy E_K of a satellite in orbit varies with its distance r from the centre of a planet of radius R.

Which one of the following graphs best shows the variation of its E_K with r?

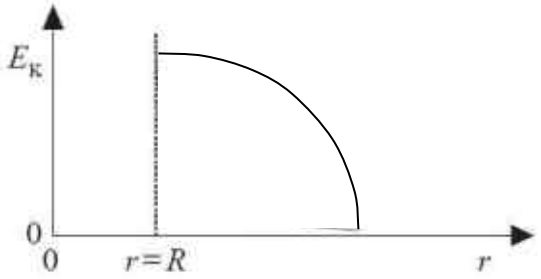
A



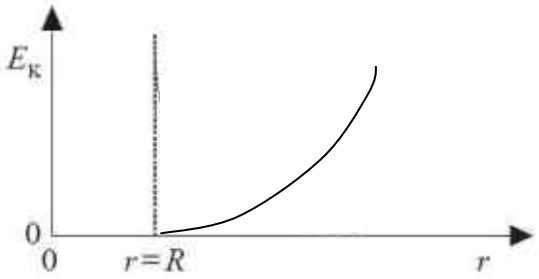
B



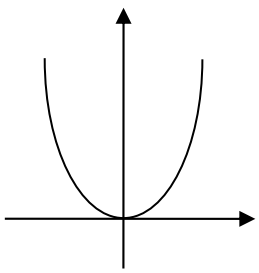
C



D



15 The diagram shows one possible graph for an object undergoing simple harmonic motion.



Which quantities have been plotted to produce this graph?

A acceleration and time

B kinetic energy and displacement

C potential energy and displacement

D kinetic energy and time

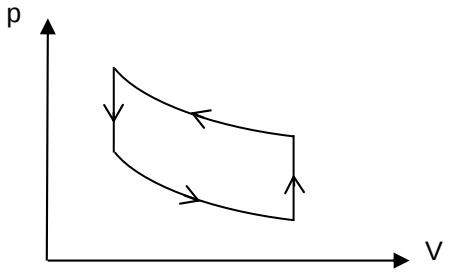
16 A mass attached to the lower end of a spring oscillates about its equilibrium position

At which points in the path of the mass do the gravitational potential energy of the mass (GPE), the elastic potential energy in the spring (EPE) and the kinetic energy of the mass (KE) have their highest values?

	GPE	EPE	KE
A	bottom	middle	top
B	bottom	top	middle
C	top	bottom	middle
D	top	bottom	top

17 An ideal gas undergoes a cycle of processes as shown in the p-V diagram.

Which statement correctly describe the situation?



A The internal energy of the gas increases over one complete cycle.

B The gas gives out more heat than it absorbs over the whole cycle.

C Over the entire cycle, the gas absorbs heat and does net work on its environment.

D The two curved portions of the graph represent adiabatic process.

18 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.

19 The first law of thermal dynamics may be expressed as shown.

$$\Delta U = q + W$$

where ΔU is the change in internal energy,

q is the heating of the system,

W is the work done on the system.

A fixed mass of ideal gas at high pressure is contained in a balloon. The balloon suddenly bursts, causing the gas to expand and cool.

In this situation, which row describes the values of ΔU, q and W ?

	ΔU	q	W
A	negative	negative	positive
B	negative	zero	negative
C	positive	zero	negative
D	positive	negative	positive

20 Which of the following about polarisation is TRUE?

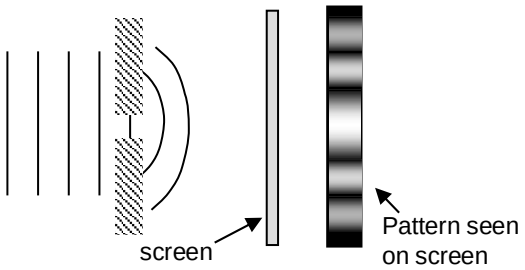
A Sound wave produced by a tuning fork can be polarised

B All electromagnetic waves can be polarised

C Polarisation restrict the vibration of a wave to the vertical direction

D When unpolarised light of intensity I_o, passes through a polariser, the intensity of the light transmitted I' is given by Malus' law where $I' = I_o \cos^2\theta$ and θ is the angle between the vertical and the transmission axis of the polariser.

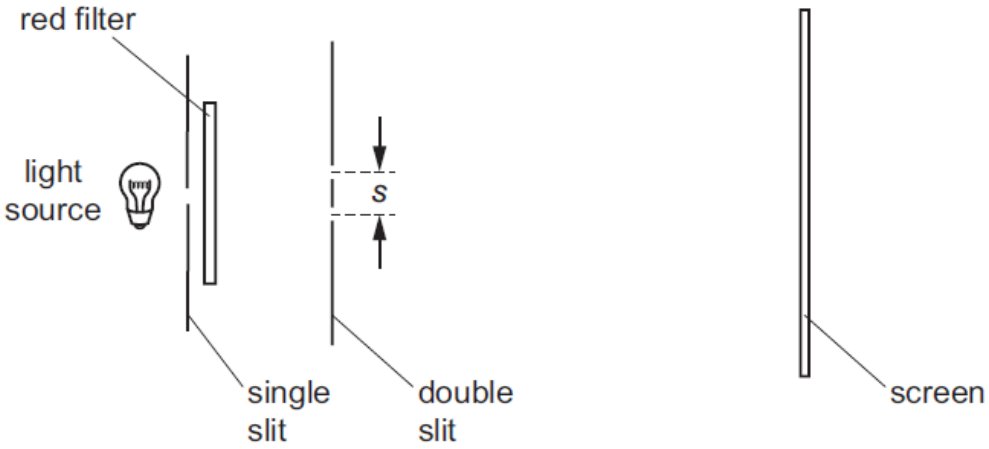
21 A student carried out an experiment on diffraction of water waves in a ripple tank. He passed plane water waves through a single slit, where the wavelength of water waves is comparable to the slit separation. He obtained the following results.



What is the best explanation for the interference pattern seen on the screen?

A The waves reflected from the surrounding walls
B The waves are not coherence
C There are secondary wavelets within the single slit
D There are secondary wavelengths within the plane wave

22 A student sets up an experiment to investigate double-slit interference of light but finds that the interference fringes observed on the screen are too close to each other to be distinguished.



Which change would help the student to distinguish the fringes?

A decrease the distance *s* between the two slits

B increase the width of each slit

C move the screen closer to the light source

D use a blue filter instead of a red filter

23 Monochromatic light of wavelength 650 nm is incident normally on a diffraction grating. The angle between the two third-order beams is 56°.

What is the spacing of the lines on the grating?

A 2.4 μm **B** 2.8 μm **C** 4.2 μm **D** 7.2 μm

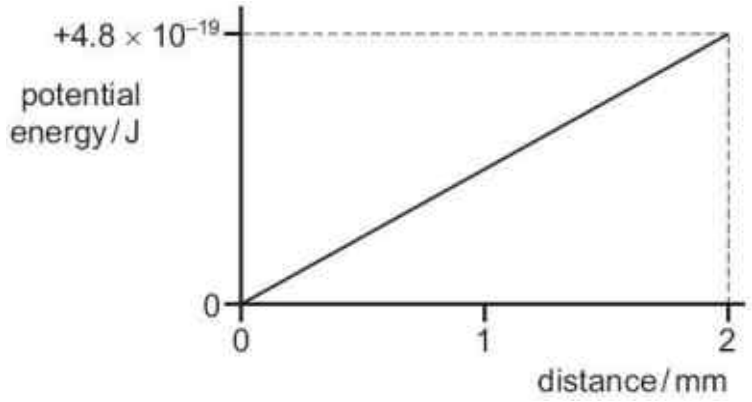
24 When two point charges, each +*Q*, are distance *r* apart, the force between them is *F*.

What is the force between point charges of +*Q* and +2*Q* when they are distance $\frac{r}{2}$ apart?

A *F* **B** 2 *F* **C** 8 *F* **D** 16 *F*

25 Two parallel plates R and S are 2.0 mm apart in a vacuum. An electron with charge -1.6×10^{-19} C moves along a straight line in the electric field between the plates.

The graph shows how the potential energy of the electron varies with its distance from plate R.



Which deduction is not correct?

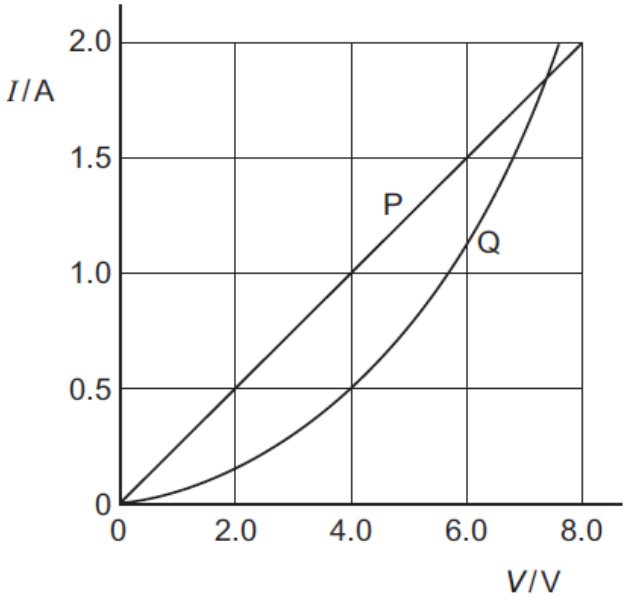
A The electric field between R and S is uniform.
B The electric field strength is 3000 N C^{-1}.
C The force on the electron is constant.
D The magnitude of the potential difference between R and S is 3 V.

26 The current in a component is reduced uniformly from 100 mA to 20 mA over a period of 8.0 s.

What is the charge that flows during this time?

A 160 mC **B** 320 mC **C** 480 mC **D** 640 mC

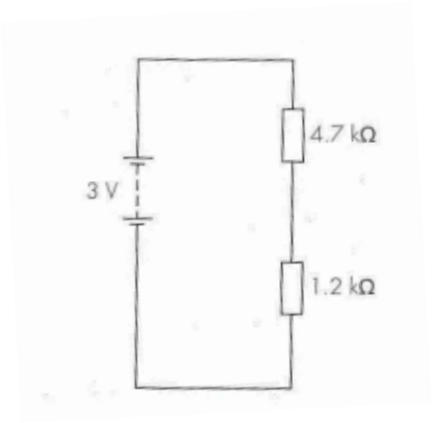
27 The I-V characteristics of two electrical components P and Q are shown below.



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.

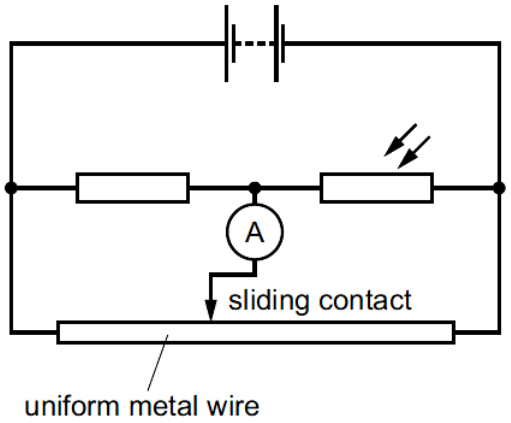
28 A student wants to use a voltmeter to measure the potential difference across the 1.2 kΩ resistor.



What is smallest resistance a voltmeter can have if it is to measure the potential difference across the 1.2 kΩ resistor without introducing a systematic error of more than 1%?

A 0.60 kΩ **B** 1.2 kΩ **C** 60 kΩ **D** 95 kΩ

29 In the potentiometer circuit shown, the reading on the ammeter is zero.



The light-dependent resistor (LDR) is then covered up and the ammeter gives a non-zero reading.

Which change could return the ammeter reading to zero?

A Decrease the supply voltage.
B Increase the supply voltage.
C Move the sliding contact to the left.
D Move the sliding contact to the right.

30 An electron is projected with velocity v into a region where there exist a uniform electric field of strength E perpendicular to a uniform magnetic field of flux density B.

If the electron velocity is to stay constant, v must be

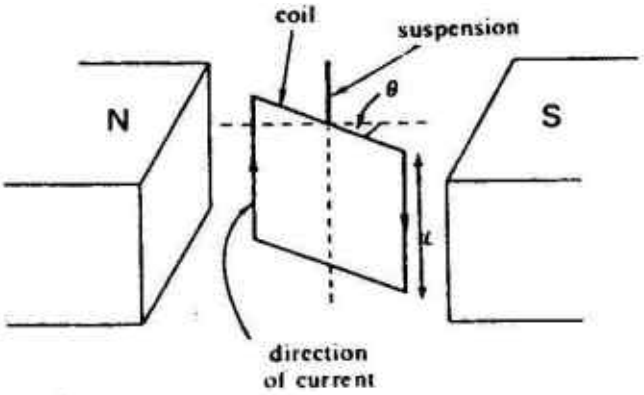
A of magnitude $\frac{B}{E}$ and parallel to B.

B of magnitude $\frac{E}{B}$ and parallel to E.

C of magnitude $\frac{B}{E}$ and perpendicular to both E and B.

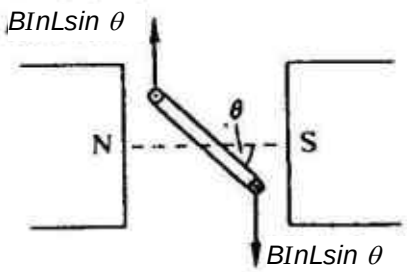
D of magnitude $\frac{E}{B}$ and perpendicular to both E and B.

31 A current I is carried by a square coil of n turns and side L suspended vertically as shown in a uniform horizontal magnetic field of flux density B.

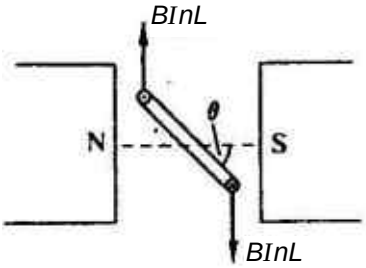


Which one of the following plan (*top-view*) diagrams correctly shows the magnitude and direction of the forces acting on the vertical sides of the coil?

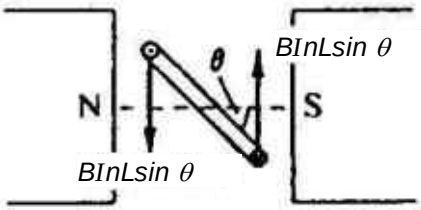
A



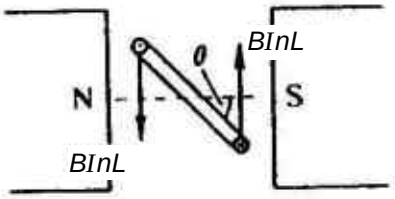
B



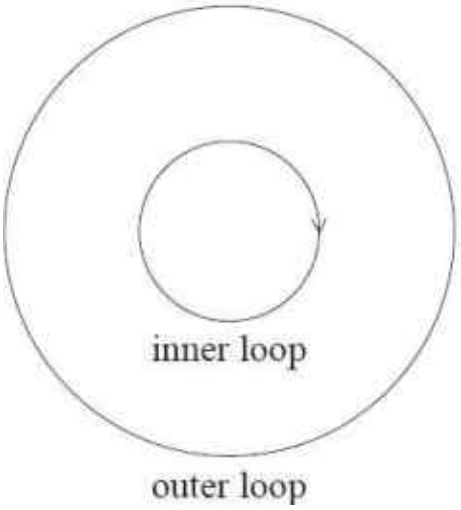
C



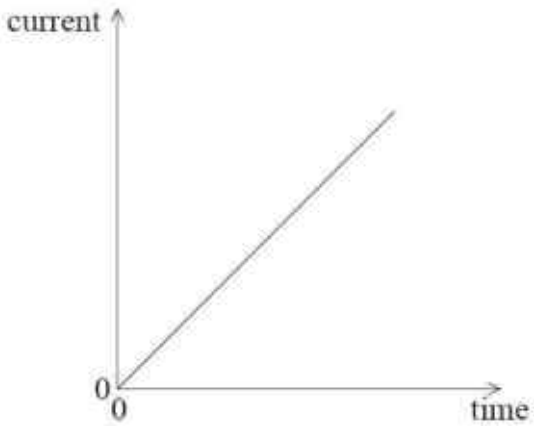
D



32 The diagram below shows two concentric loops lying in the same plane.



The current in the inner loop is clockwise and increases with time as shown in the graph below.



The induced current in the outer loop is

A constant in the clockwise direction.
B constant in the anticlockwise direction.
C variable in the clockwise direction.
D variable in the anticlockwise direction.

33 Two light bulbs are glowing at the same brightness. One is supplied with alternating current and the other with direct current. Both bulbs have a resistance of 4 Ω (assumed constant). The direct current bulb draws 3 A at 12 V.

What is the peak value of the current in the alternating current bulb?

A 1.5 A **B** 2.1 A **C** 3 A **D** 4.2 A

34 Electrons gain kinetic energy and accelerate when a potential difference is applied.

Through what potential difference (p.d.) must electrons be accelerated so they will have
(a) the same wavelength as an x-ray of wavelength 0.150 nm , and
(b) the same energy as the x-ray of 0.150 nm ?

	p.d. to accelerate electrons to have the same wavelength as an x-ray of wavelength 0.150 nm	p.d. to accelerate electrons to have the same energy as the x-ray of 0.150 nm
A	67 V	67 V
B	67 V	8300 V
C	8300 V	67 V
D	8300 V	8300 V

35 Which one of the following shows the correct sequence of events in a helium-neon laser?

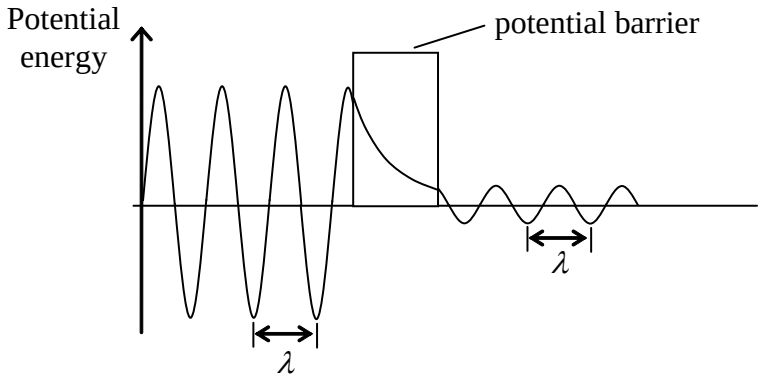
A Neon atoms excite helium atoms to a metastable state. Excited helium atoms undergo stimulated emission of red light to a lower energy state followed by spontaneous emission to ground state.

B Neon atoms excite helium atoms to a higher energy state. Excited helium atoms undergo spontaneous emission to a metastable state followed by stimulated emission of red light to ground state.

C Helium atoms excite neon atoms to a metastable state. Excited neon atoms undergo stimulated emission of red light to a lower energy state followed by spontaneous emission to ground state.

D Helium atoms excite neon atoms to a higher energy state. Excited neon atoms undergo spontaneous emission to a metastable state followed by stimulated emission of red light to ground state.

36 The diagram below shows the wave function of a particle tunnelling through a potential energy barrier from the left. It is observed that the amplitude of the wave function decreases upon passing through the barrier, but that the wavelength λ remains constant.



What deductions can be made from these two observations?

	Amplitude of the wave function decreases	**Wavelength λ remains constant**
A	Mass of the particle reduces upon passing through the barrier.	Momentum of the particle remains unchanged after passing through the barrier.
B	Intensity of the particle reduces upon passing through barrier.	Energy of the particle remains unchanged after passing through the barrier.
C	Energy of the particle reduces upon passing through the barrier.	Momentum of the particle remains unchanged after passing through the barrier.
D	Reduced probability of finding the particle after the barrier.	Energy of the particle remains unchanged after passing through the barrier.

37 An electron is incident on a rectangular potential barrier with a kinetic energy of 2.0 eV. The barrier height is 6.0 eV and its width is $d = 1.0 \times 10^{-10}$ m.

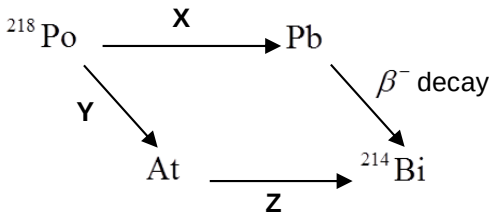
If the width of the barrier is increased to d' and the transmission coefficient is halved, the ratio $\frac{d'}{d}$ is

A 0.50 **B** 0.76 **C** 1.3 **D** 2.0

38 Rutherford's alpha-particle scattering experiment established that

A most of the mass of the atom is concentrated at the nucleus.
B the nucleus is made up of protons and neutrons.
C electrons have a negative charge.
D electrons revolve around the nucleus.

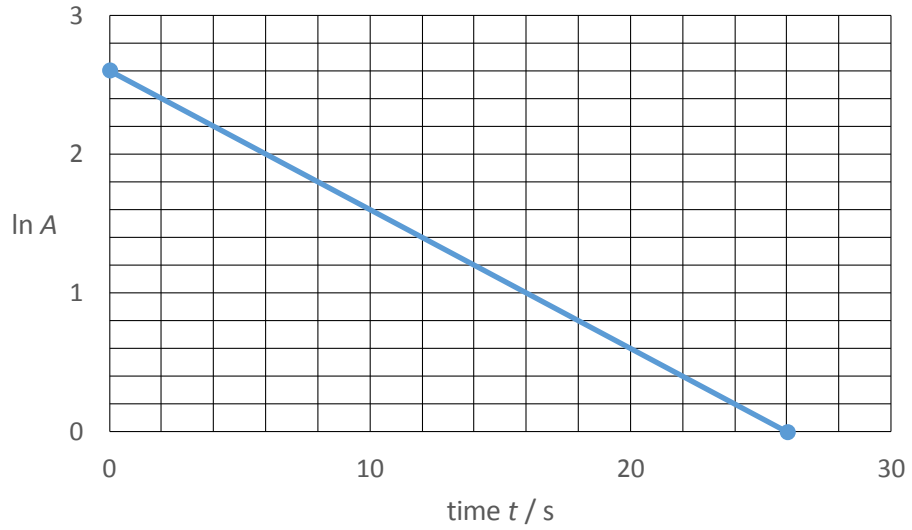
39 ^{218}Po decays to ^{214}Bi via two pathways as shown in the figure below:



What are the possible radioactive decay modes **X**, **Y** and **Z**?

	X	Y	Z
A	α decay	α decay	β^- decay
B	α decay	β^- decay	α decay
C	α decay	β^- decay	γ decay
D	γ decay	α decay	β^- decay

40 The graph below shows how the count-rate A of a radioactive source as measured by a Geiger counter varies with time t.



The relationship between A and t is

A $A = 2.6\, e^{-0.1t}$
B $A = 2.6\, e^{-10t}$
C $A = 13\, e^{-0.1t}$
D $A = 13\, e^{-10t}$

H

Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME						CLASS		
CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER		

PHYSICS **9646/02**

Paper 2 Structured Questions 24 August 2016
1 hour 45 minutes

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.
It is recommended that you spend about 1 hour 15 minutes on this 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 Examiners' use only	
1	/ 8
2	/ 7
3	/ 8
4	/ 7
5	/ 7
6	/ 7
7	/ 16
8	/ 12
Total	/ 72

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_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	=	$-\frac{Gm}{r}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

For Examiner's Use

1 Fig. 1.1 shows an aeroplane flying horizontally at a steady speed of 67 m s^{-1}. A parachutist falls from the aeroplane freely for 80 m before the parachute opens.

Assume that the air resistance is negligible.

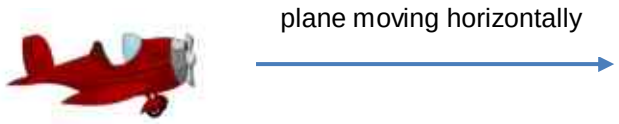


Fig. 1.1

(a) Show that the vertical component of the velocity is approximately 40 m s^{-1} when the parachutist has fallen 80 m.

[2]

(b) Determine the magnitude and direction of the resultant velocity of the parachutist at this point.

Magnitude = ... m s^{-1}

Direction = ... [3]

For Examiner's Use

(c) Sketch two labelled paths, P and Q, of the parachutist during the free fall, assuming that for path P, air resistance is negligible and for path Q, air resistance cannot be neglected.

Explain for any differences between the two paths P and Q.

[3]

For Examiner's Use

2 **(a)** State the **main** distinction between a systematic error and a random error in the measurements of a physical quantity.

[2]

(b) In a simple pendulum experiment to determine g the acceleration due to gravity, the following equation is used,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The following measurements were obtained with the help of a meter rule and stopwatch respectively.

The length of the pendulum: $l = 98.0 \pm 0.1$ cm
Average time of 10 oscillations: $t = 19.8 \pm 0.2$ s

(i) Determine the value of g with its associated uncertainty.

g = (_____ ± _____) $m\ s^{-2}$ [4]

(ii) Using a different set of apparatus, another student obtained g to be 11.15 ± 0.02 m s^{-2}.

Comment on the accuracy and precision of the two set of readings.

[1]

For Examiner's Use

3 (a) State the two conditions required for a body to be in equilibrium.

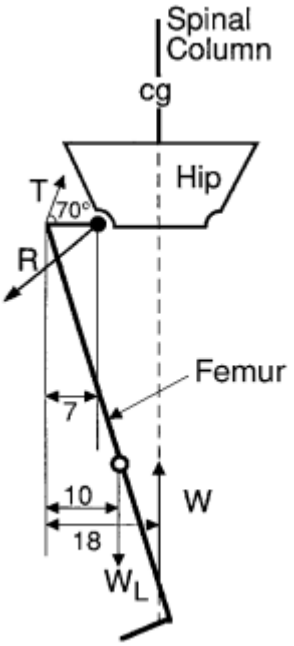
.....

.....

.....

[2]

(b) When you are walking, there is an instant when only one foot is on the ground and the centre of gravity of your body is directly over that foot. Fig. 3.1 shows the forces acting on that leg.



Source: https://medicalphysics.org/documents/WebPOTB.pdf

Fig. 3.1

The forces are the upward force on the foot equal to the weight of the body *W*; the weight of the leg W_L (which is approximately equal to *W* / 7); the reaction force by the hip on the femur *R* and the tension in the muscle group between the hip and the greater trochanter on the femur *T*.

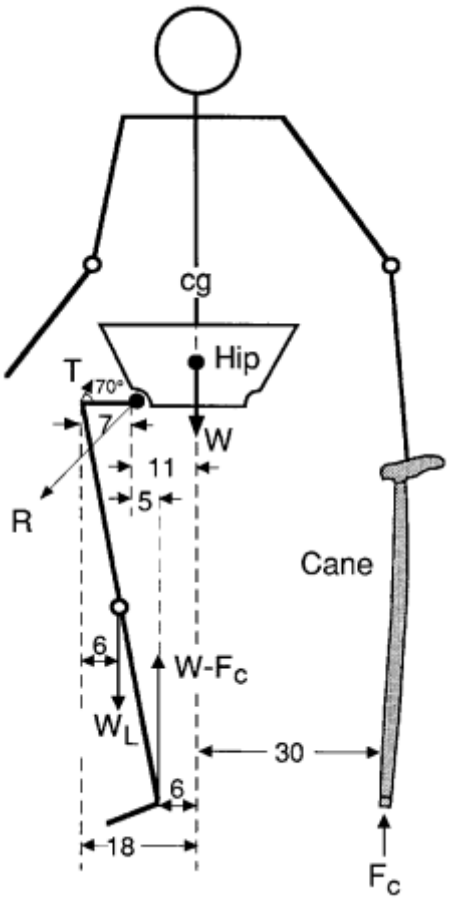
The dimensions provided are in cm.

(i) Show that $T = 1.6\ W$ and $R = 2.4\ W$.

[4]

For Examiner's Use

(ii) The use of crutches or a cane can reduce the force on the hip joint. Fig. 3.2 shows the effect of the use of a cane on the body.



Source: https://medicalphysics.org/documents/WebPOTB.pdf

Fig. 3.2

Note that the cane is in the hand opposite to the injured hip and the force pushing upward on the cane F_C reduces the upward force on the foot.

Explain qualitatively how the cane can reduce the force on the hip joint.

……

……

……

……

……

…… [2]

For Examiner's Use

4 A 3.00 g copper coin at 25.0 ^{o}C drops 50.0 m to the ground.

(a) The copper is said to possess internal energy.

Explain what is meant by the internal energy of the copper coin.

.....

.....

..... [2]

(b) Assuming that 60.0 % of the change in potential energy of the coin-Earth system goes to increasing the internal energy of the coin.

Determine the coin final temperature given that the specific heat capacity of copper is 385 J kg^{-1} K^{-1}.

Final temperature = ... ^{o}C [4]

(c) State and explain if your result in (b) depends on the mass of the coin.

.....

.....

..... [1]

For Examiner's Use

5 In x-ray production, electrons are accelerated through a high voltage and then decelerated by striking a target. A continuous x-ray spectrum can then be detected.

(a) Explain how x-ray photons can be produced by the above process.

[2]

(b) A cutoff wavelength λ_{min} is one of the features that exist in the continuous x-ray spectrum.

Show that the relationship between λ_{min} and V where V is the accelerating potential in the X-ray tube *is given by*

$$\lambda_{min} = \frac{hc}{eV}$$

where h and c are the Planck's constant and speed of light in vacuum respectively.

Explain your working clearly.

[2]

(c) **(i)** In a particular x-ray tube, the accelerating potential difference is 50 kV and the cutoff wavelength is at 2.50×10^{-11} m.

Determine a value for the Planck constant.

Planck constant = …… J s [1]

(ii) Suggest a suitable experiment using cutoff wavelength limit of the continuous x-ray spectrum to determine a better estimate of the value of the Planck constant.

……

……

…… [2]

For Examiner's Use

6 (a) By reference to the photoelectric effect, state what is meant by the threshold frequency.

.....

.....

[1]

(b) Electrons are emitted from a metal surface when light of a particular wavelength is incident on the surface.

Explain why the emitted electrons have a range of values of kinetic energy below a maximum value.

.....

.....

[2]

(c) The wavelength of the incident radiation is λ in a Photoelectric Effect experiment.

The variation with $1/\lambda$ of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is shown in Fig. 6.1.

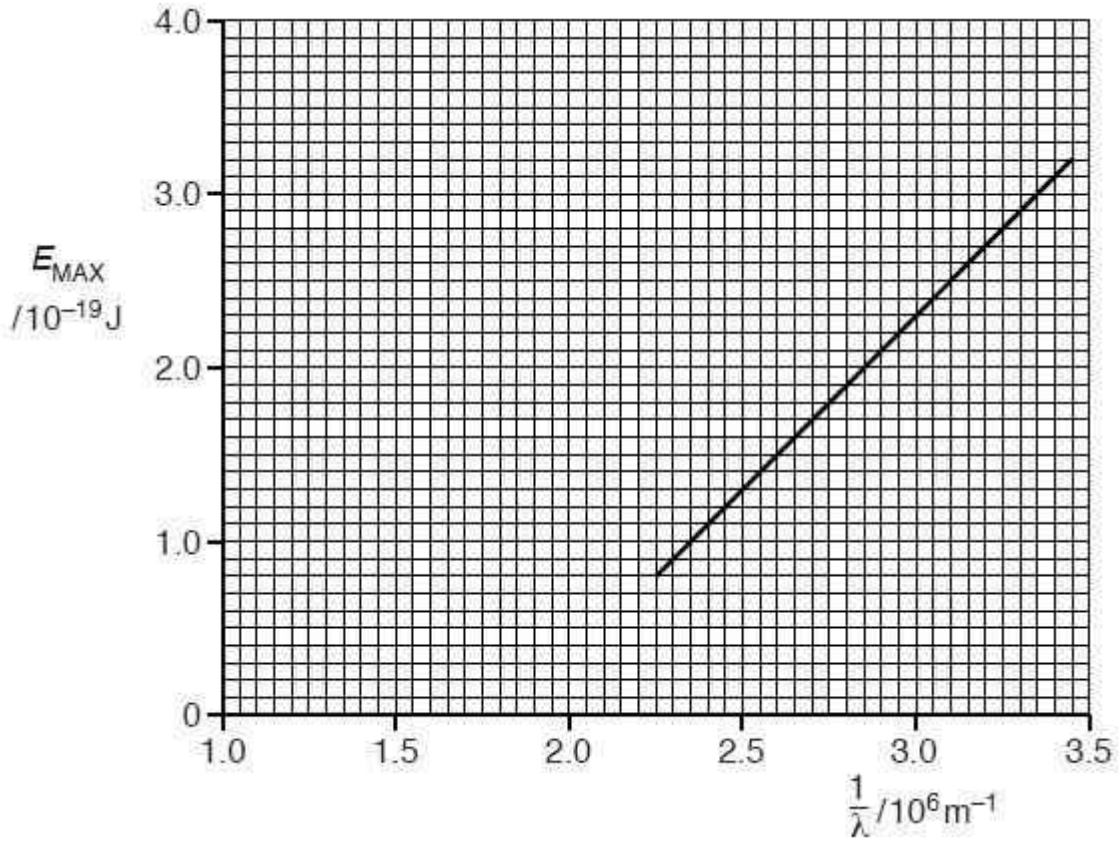


Fig. 6.1

For Examiner's Use

Using the data from Fig. 6.1, determine

(i) the work function energy Φ.

Φ = ... J [1]

(ii) the associated *de Broglie's wavelength* of the electron that was emitted with the maximum kinetic energy when a frequency of 7.5 x 10^{14} Hz falls on the metal.

de Broglie's wavelength = ... m [3]

For Examiner's Use

7 An **earthquake** is the perceptible shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's crust. This sudden motion causes shock waves (seismic waves) to radiate from their point of origin called the focus and travel through the earth. It is these seismic waves that can produce ground motion which people call an earthquake.

Vibrations from an earthquake are categorised as P, S or L seismic waves. They travel through the Earth in different ways and at different speeds. They can be detected and analysed.

P-waves (P stands for **primary**) arrive at the detector first. They are *longitudinal waves*. These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves.

S-waves (S stands for **secondary**) arrive at the detector of a seismometer seconds later. They are *transverse waves*. S-waves can travel only through solids.

L-waves (L stands for **long**) are the slowest, travel over the surface and causes the most damage.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with depth and rock type. P waves travel between 6.0 and 13 km s^{-1} and S waves are slower and travel between 3.5 and 7.5 km s^{-1}.

In earthquake seismology, the time interval between the first arrivals of transverse (S) and longitudinal (P) waves, is proportional to the distance from the earthquake source.

In order to locate the epicenter of an earthquake you will need to examine its seismograms as recorded by at least three different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). The S - P time interval will then be used to determine the distance the waves have traveled from the epicenter to that station.

(a) Distinguish between longitudinal and transverse waves.

.....

.....

.....

.....

..... [2]

For Examiner's Use

(b) **Fig. 7.1** shows a structure of the Earth's interior and regions where P or S-waves may not be detected.

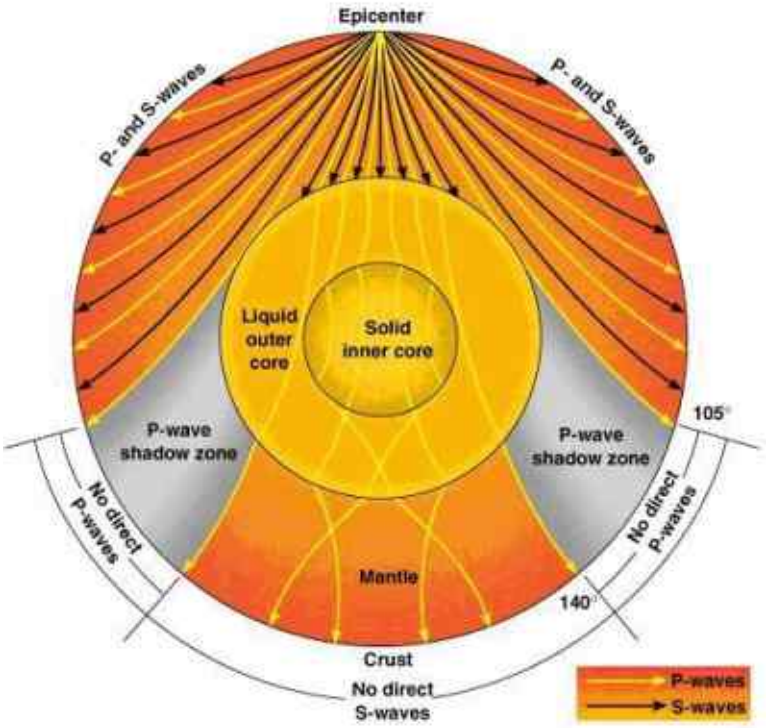


Fig. 7.1

Explain why no S-waves are detected directly opposite the epicenter.

.....

..... [1]

(c) Fig. 7.2 shows the variation with distance (in kilometers) from the epicenter of the time (in seconds) taken for the S and P waves to reach the seismic station from the epicenter.

Fig 7.3 shows three seismographs from **Akita, Pusan and Tokyo Seismic Stations** of the earthquake that occurred in 1995, in the Kansai area of Japan near Kobe, called the Kobe earthquake. This earthquake took place near major population centers and caused significant loss of life and property damage.

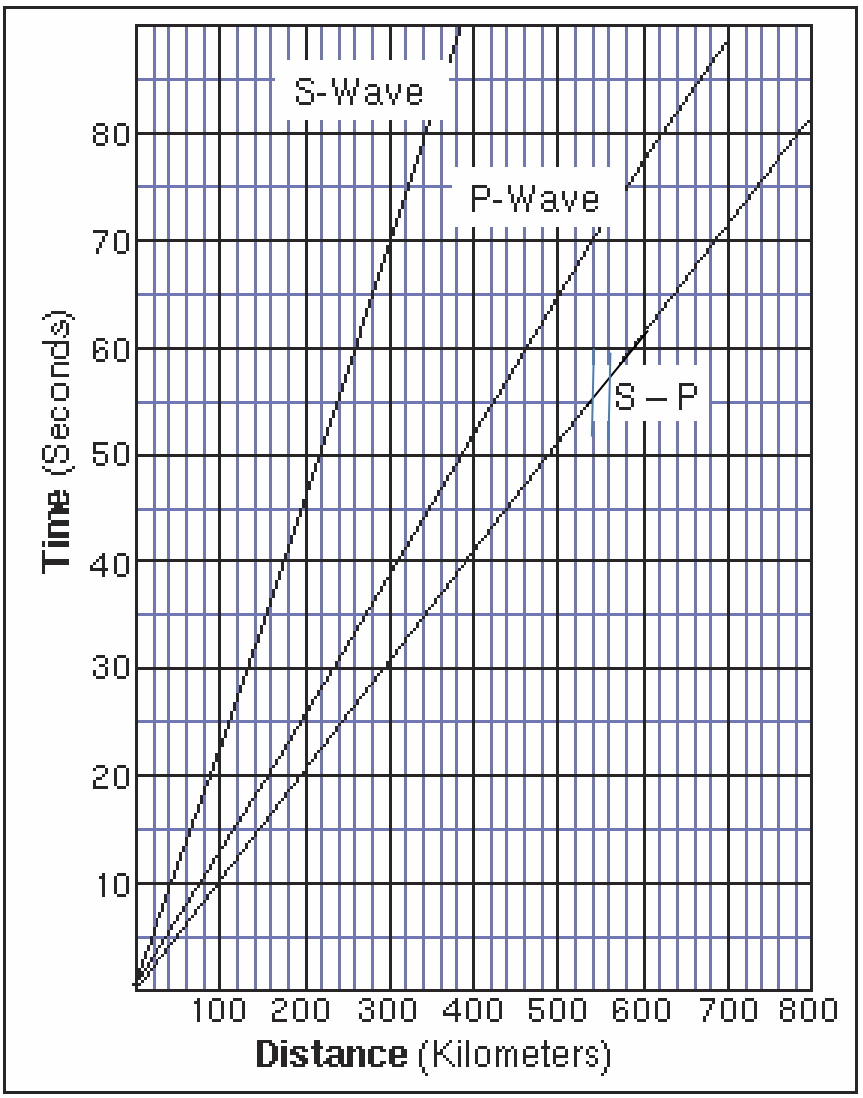
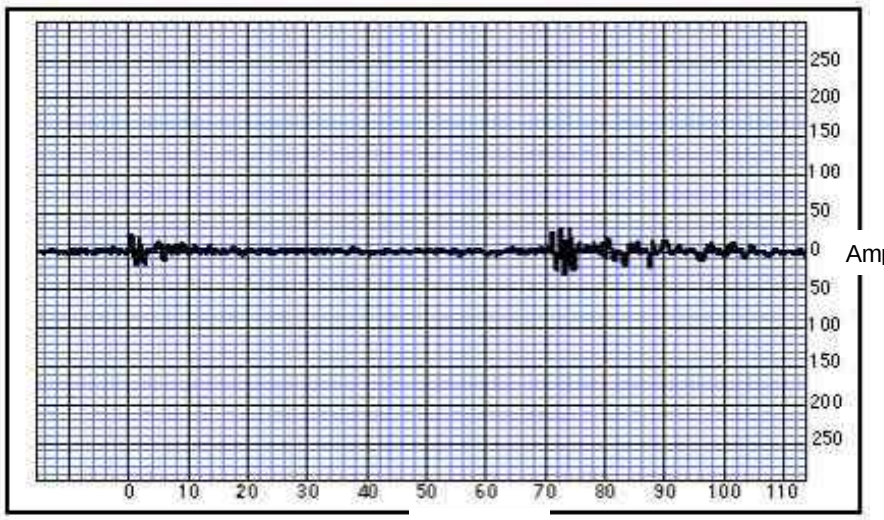


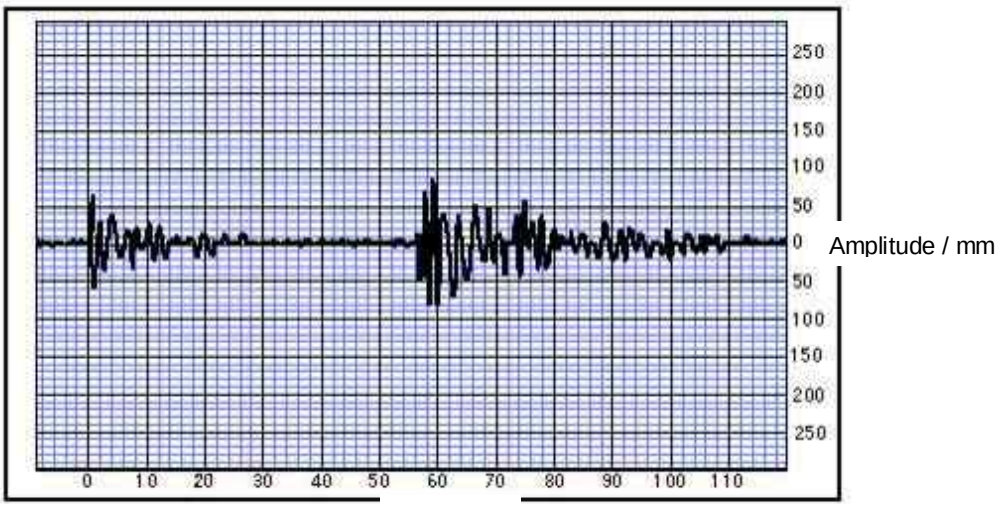
Fig. 7.2

(Source: http://engineeringseismologywithmearul.blogspot.sg/)

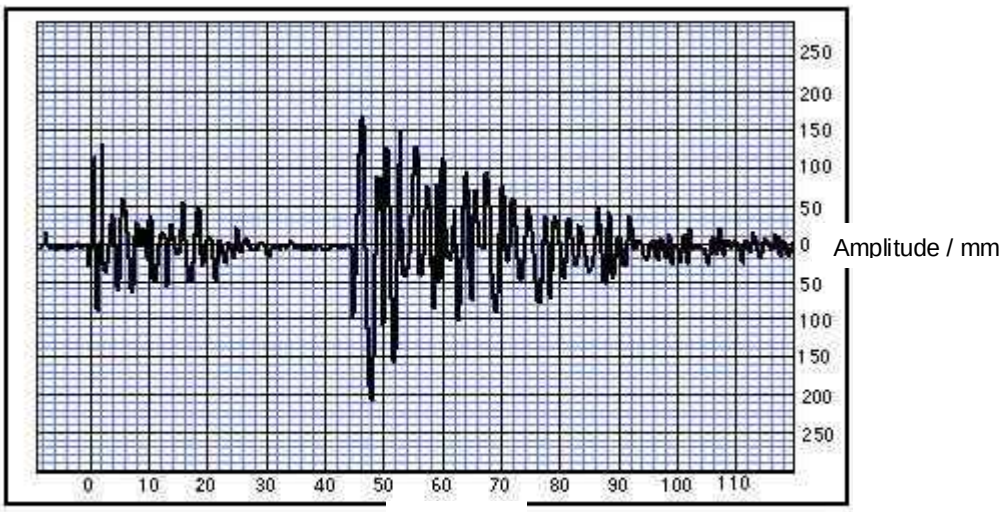
For Examiner's Use



Akita Seismic Station



Pusan Seismic Station



Tokyo Seismic Station

Fig 7.3 Seismograms from Akita, Pusan and Tokyo Stations
(Source: http://www.geo.umass.edu)

For Examiner's Use

(i) Using the data given in Fig. 7.2 and Fig. 7.3, complete Fig. 7.4

SEISMOGRAPH STATION	Difference in Arrival Time between P and S waves / s	Distance to Epicenter / km	Amplitude of the S wave /mm
AKITA	71	695	
PUSAN			90
TOKYO	44		

Fig. 7.4

[3]

(ii) Hence determine the approximate location of the epicenter of the earthquake on the location map in Fig. 7.5. Label your location "**X**"



Fig. 7.5

[3]

For Examiner's Use

(iii) The intensity of an earthquake on the Richter scale can be easily determined using a nomogram as shown in Fig. 7.6

For each station, connecting the distance on the Distance scale and the amplitude on the Amplitude scale with a straight line, the intersection on the Magnitude scale is the Richter scale reading for the earthquake.

If distance of the station from the earthquake's epicenter is 100 km and amplitude of the earthquake recorded at the station is 1 mm, the magnitude of the earthquake is 3.0 on the Richter scale, as shown in the sample line drawn in Fig. 7.6.

1. State one other factor that may affect the amplitude of the S-wave recorded besides the intensity of the Earthquake.

…….. [1]

2. Using your answers from Fig. 7.4 and the nomogram in Fig 7.6, construct and determine the magnitude of the earthquake on the Richter scale.

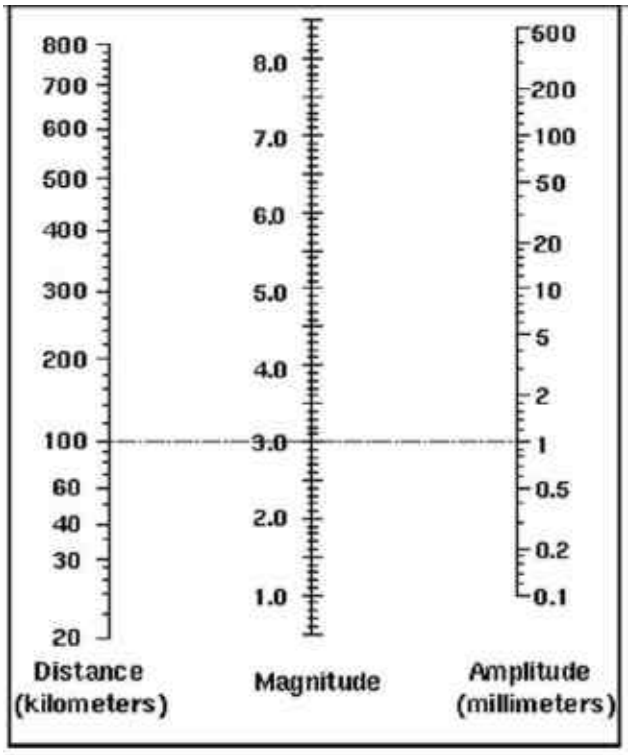


Fig 7.6

Magnitude = …….. [2]

For Examiner's Use

(d) The Richter magnitude scale used in (c) was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. The magnitude of an earthquake on a Richter Scale M is related to the intensity (I) of the S-wave according to the equation

$$M = \log\left(\frac{I}{I_o}\right)$$

where I_o is a reference intensity.

The amount of energy radiated by an earthquake is a measure of the potential for damage to man-made structures. The Richter magnitude M, is related to the energy released E in ergs (1 erg = 10^{-7} J) through the equation

$$\log E = 1.5\,M + 4.8$$

(i) On 26 Dec 2004, an underwater 9.0-magnitude earthquake off the coast of Aceh, Indonesia, sent giant tidal waves into coastal areas in Indonesia, Thailand, Malaysia, Sri Lanka, Bangladesh, India, Myanmar, the Maldives and Somalia, resulting in at least 159 000 people dead. This is known as the great Sumatra Earthquake

1. Determine the ratio of the intensity of the Sumatra Earthquake to the Kobe Earthquake

Ratio = …….. [1]

2. Hence explain why we use the Richter scale, which is a logarithmic scale, instead of just a normal scale based on the intensity I.

.....

.....

[1]

.....

(ii) Determine the ratio of the energy released from the Sumatra Earthquake to the Kobe Earthquake.

Ratio = …….. [1]

(e) The death toll in the 2015 Chile Illapel Earthquake with magnitude 8.3 was 14 whereas that from the 2015 Nepal Earthquake with magnitude 7.8 was almost 9000.

Suggest a possible reason why higher magnitude earthquakes may not always lead to higher death tolls.

.....

[1]

8 A student is investigating the flow of water through a horizontal tube.

The rate *Q* (volume per unit time) at which water flows through a tube depends on the pressure difference per unit length across the tube.

The student has the use of a metal can with two holes. A narrow horizontal tube goes through the hole in the side of the can. The can is continuously supplied with water from a tap. The level of water in the can is kept constant by the position of a wide vertical tube which passes through the hole in the bottom of the can as shown in Fig. 8.1. Both tubes may be moved along the holes.

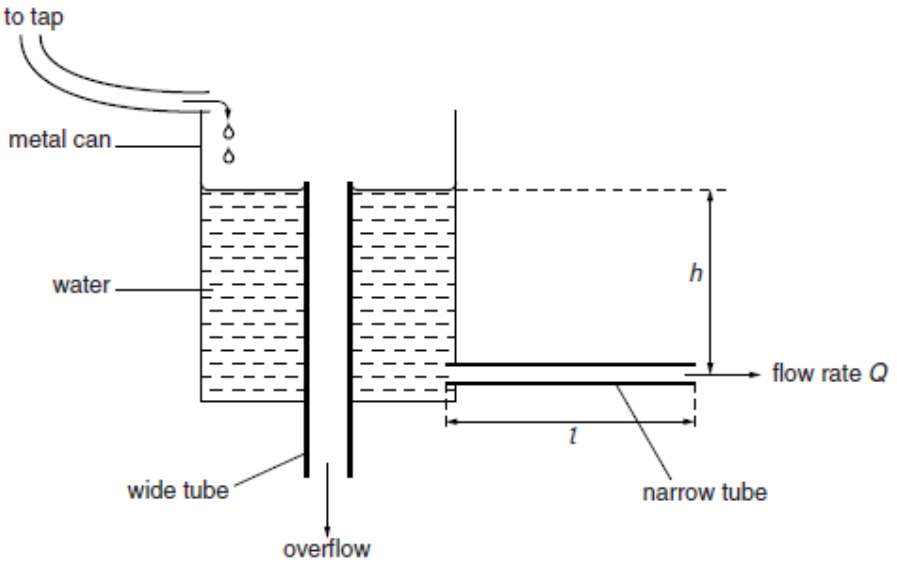


Fig. 8.1

It is suggested that the relationship between the flow rate *Q* of water through the narrow horizontal tube and the vertical height *h* is

$$Q = \frac{2\pi\rho ghd^4}{l\eta}$$

where ρ is the density of water, *g* is the acceleration of free fall, *d* is the internal diameter of the tube, l is the length of the tube and η is a constant.

Design a laboratory experiment to test the relationship between *Q* and *h* and determine a value for η.

You should draw a 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 *Q* and *h* is determined and η is obtained,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment..

For Examiner's Use

Diagram

For Examiner's Use

For Examiner's Use

[12]

Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME						CLASS		
CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER		

PHYSICS **9646/03**
Paper 3 Longer Structured Questions 25 Aug 2016
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.

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 Examiners' use only	
Section A	
1	/ 10
2	/ 10
3	/ 10
4	/ 10
Section B	
5	/ 20
6	/ 20
7	/ 20
Total	/ 80

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_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	=	$-\frac{Gm}{r}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

For Examiner's Use

Section A

Answer **all** the questions in the spaces provided.

1 (a) Define the *radian*.

[1]

(b) A small particle of mass *m* is pulled to the top of a frictionless half-cylinder of radius *R* by a cord that passes over the top of the cylinder. The force exerted by the cord is *F*. Mass *m* is moving at constant speed of 2.0 m s^{-1}.

The mass *m* is 100 g.
Radius *R* is 2.0 m.

The side-view is shown in Fig. 1.1

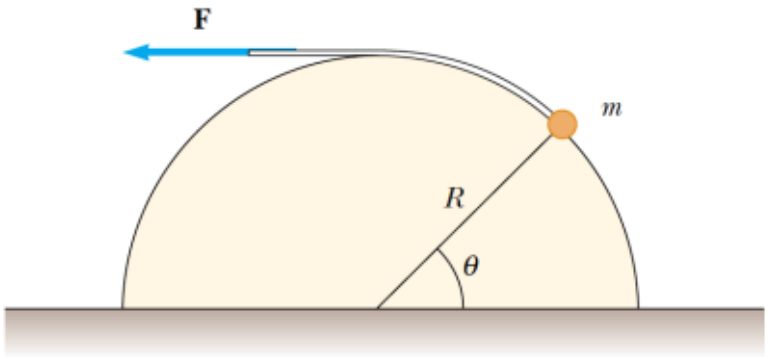


Fig. 1.1

(i) On Fig. 1.1 draw the free-body diagram for the forces acting on *m*. [2]

(ii) Hence show, with appropriate explanation, $F = mg \cos \theta$.

[1]

For Examiner's Use

(iii) The graph of how F varies with θ is given in Fig. 1.2.



Fig 1.2

State the relationship between the work done by force F and area under the $F - \theta$ graph.

.....

.....

[1]

(iv) Hence or otherwise, determine the work done by the variable force F in moving the particle at constant speed from the bottom to the top of the half cylinder.

Work done = …….. J [2]

For Examiner's Use

(v) On Fig 1.3. Sketch the variation with θ,

1. the gravitational potential energy of the mass *m* , (label it G) and
2. the kinetic energy of mass *m* (label it K).

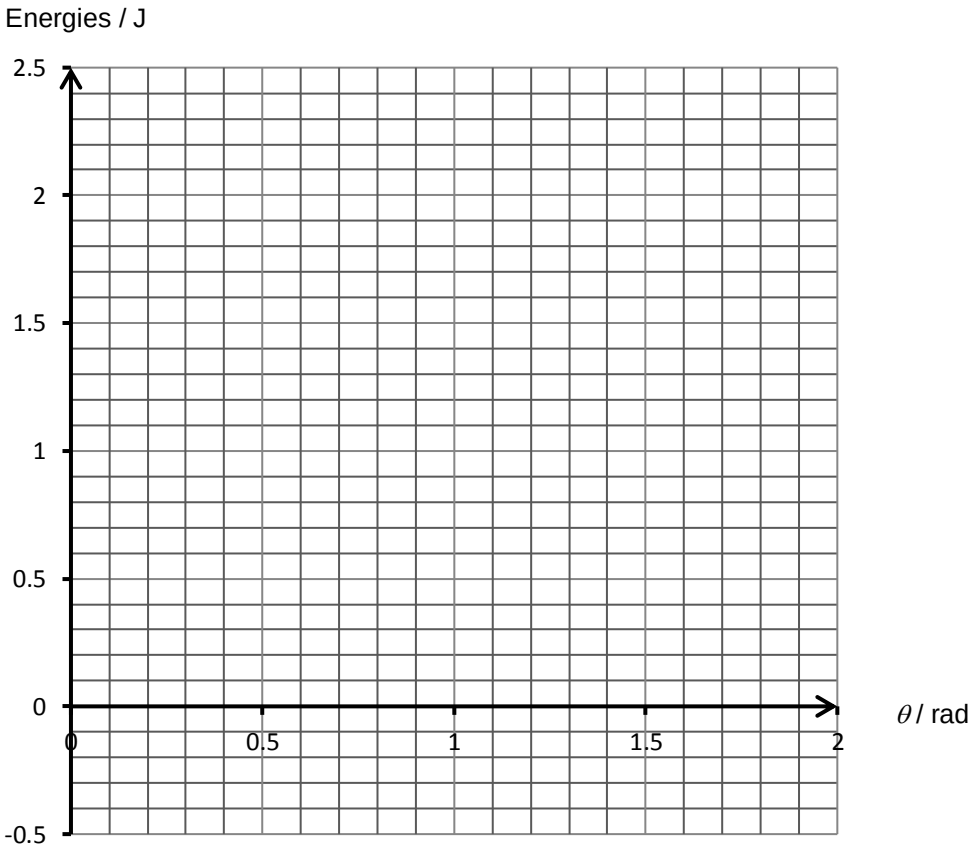


Fig. 1.3

[3]

For Examiner's Use

2 A microwave oven, shown in Fig 2.1 consists of a reflective casing on the opposite wall of the microwave source and a turntable at the bottom that rotates. It produces microwave of frequency 2.45 GHz within the oven.

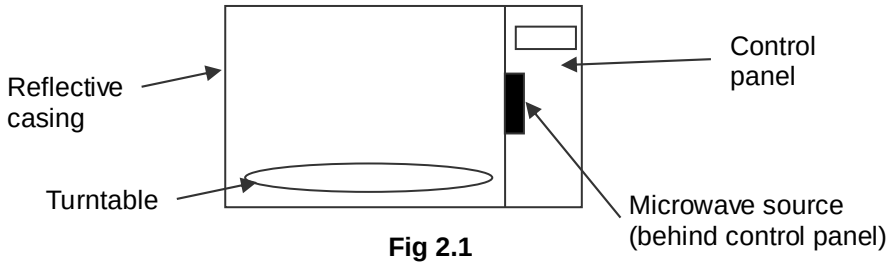


Fig 2.1

Water molecules are electric dipoles (that is, they have one positive end and one negative end). In the oscillating field of the microwave oven, the water molecules in trying to align with the changing field, oscillate rapidly. Thus the water molecules in the food get heated up and hence the food gets heated up.

(a) Explain how standing waves are formed inside the microwave oven.

[3]

(b) **<u>The turntable of the oven is removed from the oven</u>** so that oven's content will not rotate during heating. A wet piece of cardboard is placed flat in a microwave oven. The cardboard is then micro-waved for a short while. Stripes of dry regions regularly spaced apart are seen on the cardboard.

(i) Explain the formation of these dry stripes and hence deduce their distances apart.

[3]

(ii) The interior of the microwave oven is 30.5 cm wide.

In the space below, **draw the amplitude-position graph** of the standing wave pattern in the oven. Mark the positions on the graph with "D" that would produce dry patches on the wet cardboard as mentioned.

[2]

For Examiner's Use

(c) **<u>The turntable of the oven is now placed back in the oven</u>**. After five minutes of cooking a dish (with live ants in it) in a microwave wave, and upon removing it, it is noticed that several ants are inside the oven apparently unharmed by the intense microwave radiation.

Explain why some of the ants survived.

.....

.....

.....

..... [1]

(d) Explain the purpose of the turntable of the microwave oven.

.....

.....

.....

..... [1]

3 Fig. 3 shows two circuit which could be used to act as a dimmer switch for a lamp.

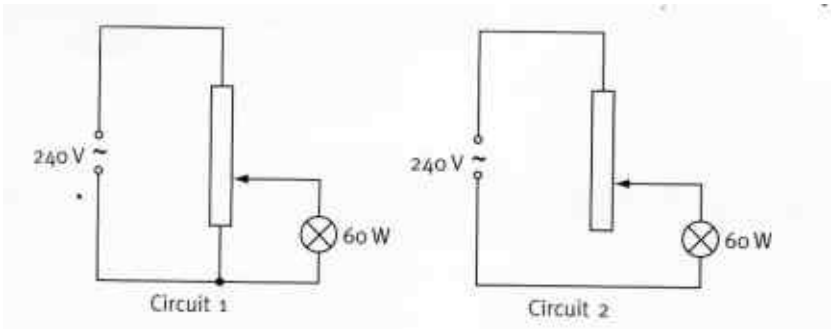


Fig. 3

(a) With reference to energy conversion in the bulbs, explain what do you understand by potential difference across the bulbs

.....

.....

..... [2]

(b) Explain **one** advantage circuit 1 has over circuit 2.

.....

.....

.....

..... [2]

For Examiner's Use

(c) One problem with circuit 1 is that there is always a current in the resistor.

With an aid of a diagram, explain how this problem could be rectified.

[2]

(d) **(i)** The lamp is rated at 60 W at 240 V.

Calculate the resistance of the lamp filament at its normal operating temperature.

resistance = ... Ω [2]

(ii) State and explain how the resistance of the filament at room temperature would compare with the value calculated in (d)(i).

[2]

For Examiner's Use

4 (a) (i) Describe how the emission line spectra can be explained using the idea of discrete electron energy levels in isolated atoms.

[2]

(ii) State the conditions and state of the atoms such that they are sufficiently isolated so that line spectra can be observed.

[2]

(b) Fig. 4 illustrates some of the electron energy levels in an isolated atom of an alkaline metal for the outer (valence) electron. Four possible electron transitions are shown.

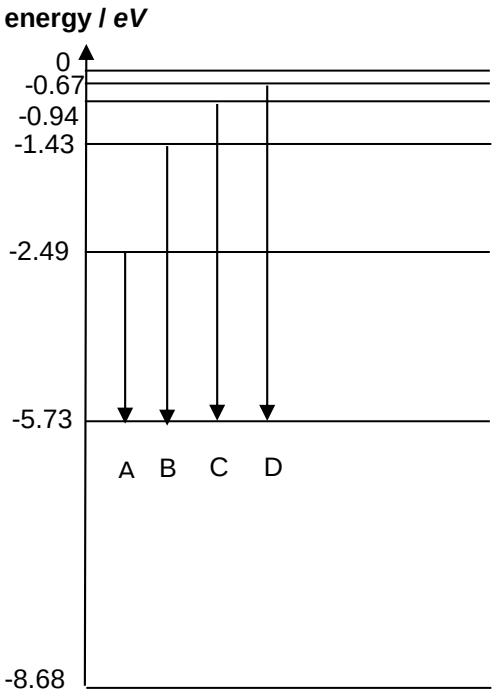


Fig. 4

For Examiner's Use

(i) Determine the energy required to remove the outer electron at the lowest energy level shown in Fig. 4 from the atom.

Energy = …… J [1]

(ii) State which of the transitions A, B, C or D in Fig 4 would lead to the emission of radiation of the shortest wavelength.

Ans ..... [1]

(iii) Calculate the wavelength of this radiation.

wavelength = …… nm [1]

(iv) State the region of the electromagnetic spectrum in which this radiation lies.

Region is ..... [1]

(c) Sketch the appearance of the spectrum in order of increasing wavelength which these four transitions produce. Label the transitions responsible for each line.

[1]

(d) The work function energy of lithium differs from the energy required to remove the outer electron from an isolated lithium atom.

Suggest why this is so.
(Hint: Work function is the minimum energy needed to remove a delocalized electron from the solid metal surface)

.....

.....

..... [1]

For Examiner's Use

Section B

Answer **two** questions for this section.

5 Fig. 5.1 below shows the decay series of Uranium-238. Uranium undergoes a series of alpha and beta decays to become a stable isotope of Lead-206 after a long period of time.

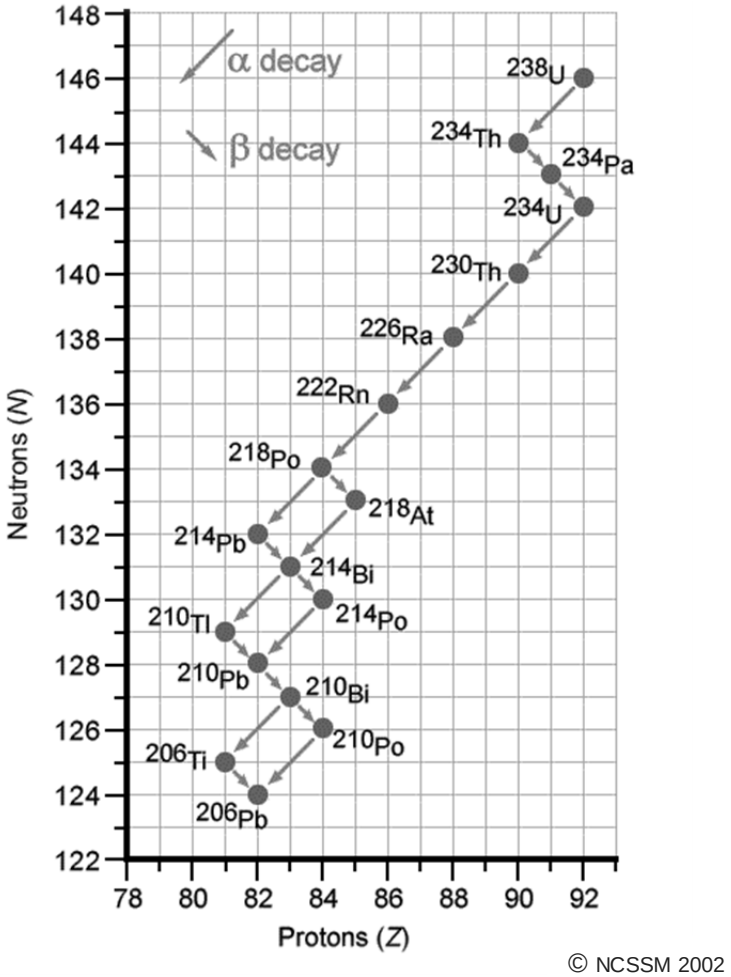


Fig. 5.1

(a) Suggest why stable nuclei tend to have a greater proportion of neutrons to protons in their nucleus.

.....

.....

[1]

(b) It can be seen that all the daughter nuclei that result from the decay of Uranium – 238 have a multiple four nucleons lesser than that of Uranium.

Explain why this is so.

.....

.....

.....

[1]

For Examiner's Use

(c) State the Principle of Conservation of Linear Momentum.

.....

.....

[2]

(d) A stationary Radon (^{222}Rn) nucleus decays spontaneously into a Polonium (^{218}Po) nucleus via an α decay. It may be assumed that no γ - ray is emitted during this decay.

The rest masses of the nuclei involved are given as shown:

Rn: 222.0176 *u*,
Po: 218.0090 *u*,
α: 4.0026 *u*,
where *u* is the unified atomic mass constant.

(i) Write down the nuclear equation which describes this decay.

[2]

.....

(ii) Show that the net energy released during this reaction is about 8.96 x 10^{-13} J

[2]

(iii) Using **(c)**, show that $\frac{\textit{Kinetic energy of } \alpha \textit{ particle}}{\textit{Kinetic energy of Po nucleus}} = \frac{218}{4}$

[5]

For Examiner's Use

(iv) Hence, calculate the speed of the α particle.

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

(e) The Polonium (Po) nucleus subsequently decays spontaneously into an Astatine (At) nucleus via a β decay. It may be assumed that no γ - ray is emitted during this decay.

Fig. 5.2 shows the variation with kinetic energy of β particles produced during the decay of the number of β particles emitted.

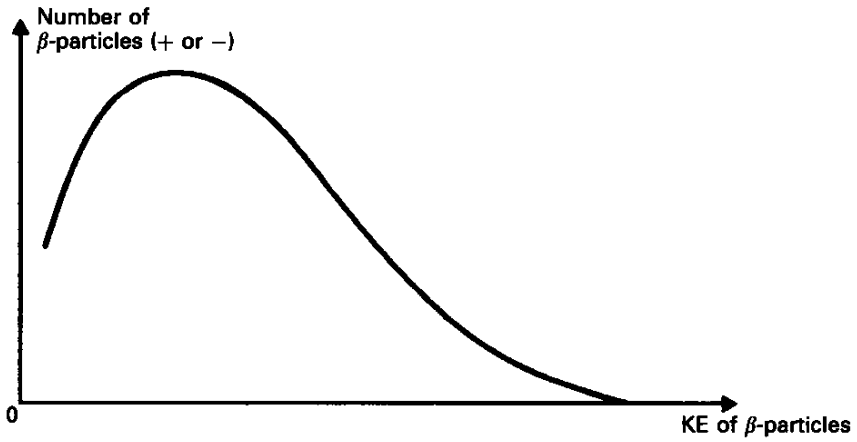


Fig. 5.2

(i) Explain how Fig 5.2 provided evidence for the discovery of the neutrino, which was emitted during a β decay.

.....

.....

..... [2]

(ii) A student suggests that the Astatine nucleus and β particle would be moving in opposite directions after the decay.

Comment on the validity of this statement.

.....

.....

..... [2]

For Examiner's Use

6 (a) State the type of field, or fields, that may cause a force to be exerted on a particle that is

(i) uncharged and moving,

[1]

(ii) charged and stationary,

[1]

(iii) charged and moving at right-angles to the field.

[2]

(b) (i) Explain what is meant by a magnetic field.

[2]

(ii) Conventionally, arrows on field lines define the direction of a force acting on an object.

State the property of the object that experiences a force **in a direction opposite** to the direction of a magnetic field.

[1]

(iii) **Fig. 6.1** shows the cross-section of two long vertical wires perpendicular to the page. The electric current in the left hand wire is downwards into the page whereas the current in the right hand wire is outwards from the page. The current in the left hand wire is greater than the current in the right hand wire.

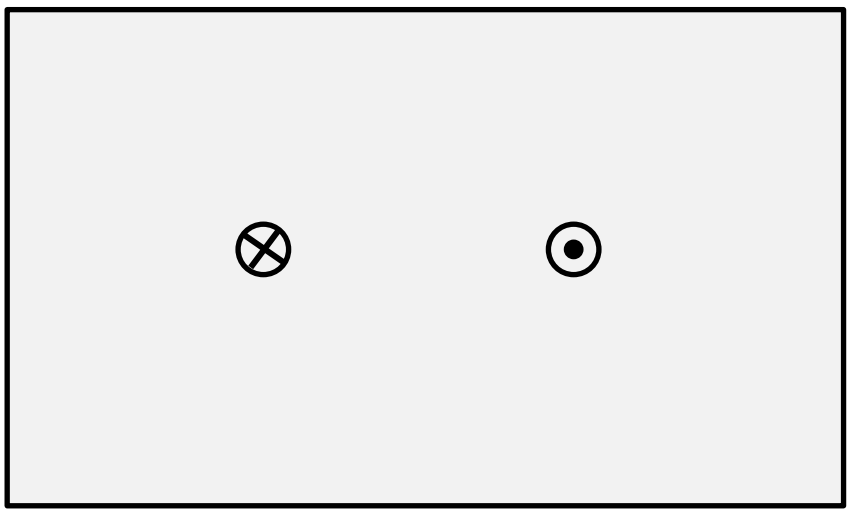


Fig. 6.1

Sketch the resultant magnetic field pattern around the wires within the shaded area. Indicate direction arrows on the field lines. [3]

For Examiner's Use

(c) The path of the negatively-charged particle travelling at constant speed before it enters a uniform magnetic field is shown in Fig. 6.2.

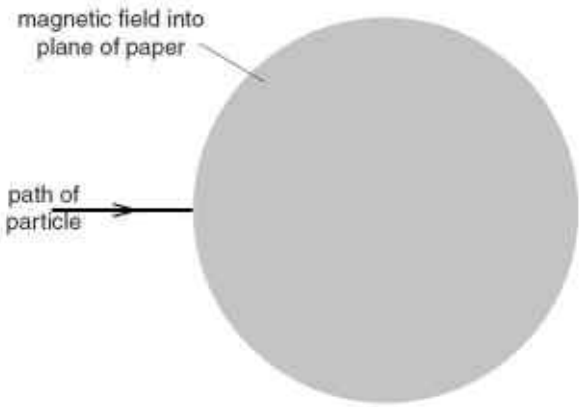


Fig. 6.2

(i) Explain why the path of the particle in the magnetic field is the arc of a circle.

.....

.....

.....

.....

[2]

(ii) On Fig. 6.2, sketch the path of the particle in the magnetic field and as it emerges from the field. [2]

(d) **(i)** Define *electric potential* at a point.

.....

.....

[2]

(ii) Two isolated point charges A and B are separated by a distance of 30.0 cm, as shown in Fig. 6.3.

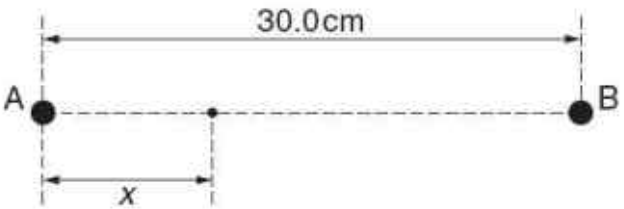


Fig. 6.3

The charge at A is + 3.6×10^{-9} C.
The variation with distance x from A along AB of the resultant electric potential V is shown in Fig. 6.4.

For Examiner's Use

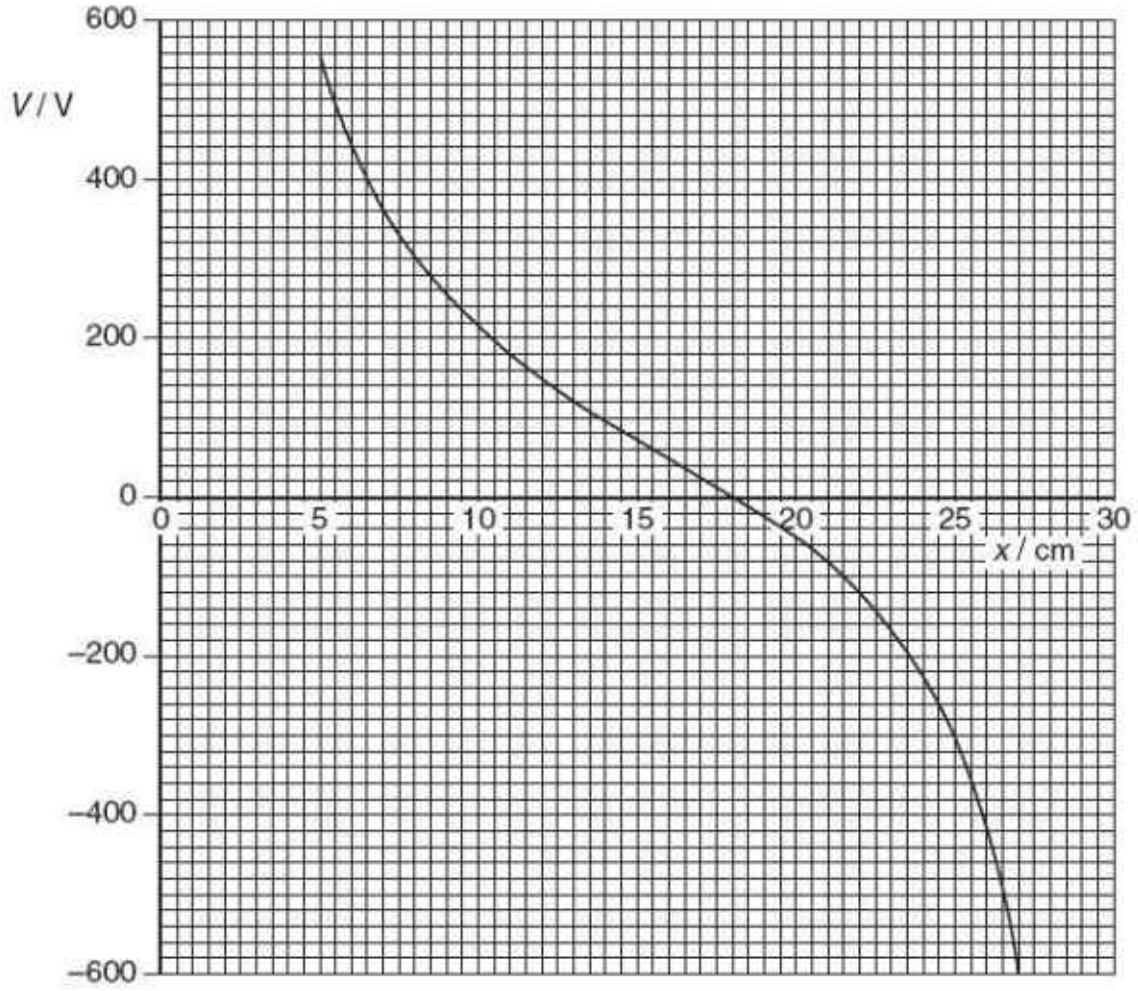


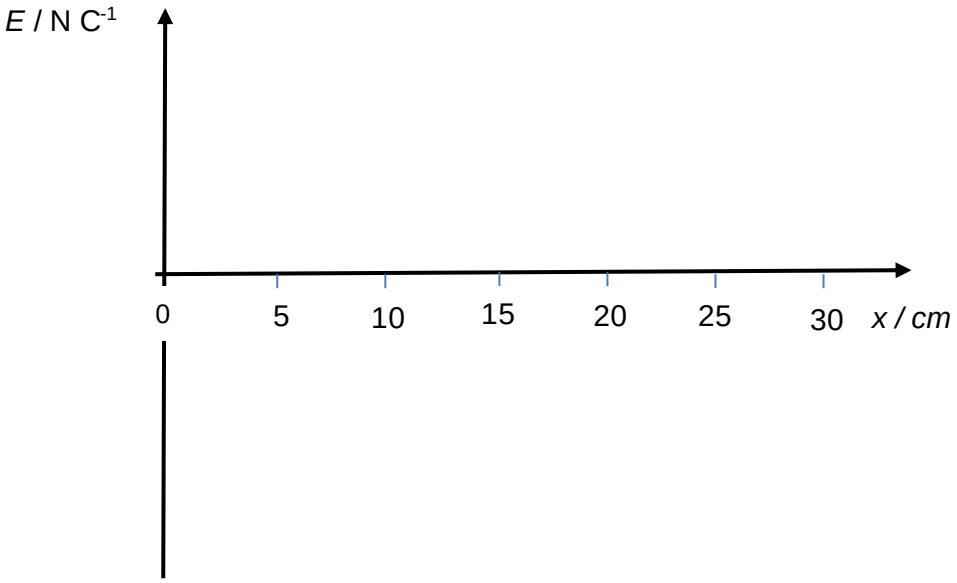
Fig. 6.4.

1. Determine the charge at B.

Charge = …… C [2]

For Examiner's Use

2. Sketch on Fig 6.5 the variation with distance *x* from A along AB of the resultant electric field strength *E* for x = 5.0 cm to 27.0 cm.
(*Calculation of actual value of E is not required*.)



[2]

Fig. 6.5

For Examiner's Use

7 (a) A conducting rectangular loop of mass *M*, resistance *R* and dimensions *w* by *l* falls from rest into a magnetic field *B* as shown in Fig. 7.1.

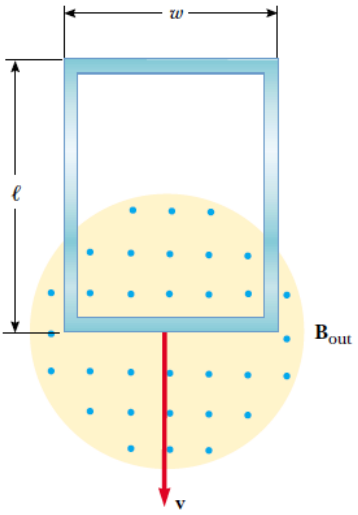


Fig 7.1

(i) **1.** During the time interval before the top edge of the loop reaches the field, the loop approaches a terminal speed v_t.

Explain why there is an electromagnetic force acting on the bottom edge of the loop but not on the top edge of the loop.

.....

.....

..... [2]

2. By considering the forces acting on the loop, or otherwise, show that $v_t = \frac{MgR}{B^2w^2}$

[3]

3. Briefly explain why v_t is dependent on *R.*

.....

.....

..... [2]

For Examiner's Use

(ii) The top of the rectangular loop is now attached with a spring of spring constant k = 12.5 N kg^{-1}, and the loop is set to oscillate. The mass M of the loop = 500 g.

Graph A in Fig 7.2 shows the variation with time, the displacement of the loop when the magnetic field is switched off.

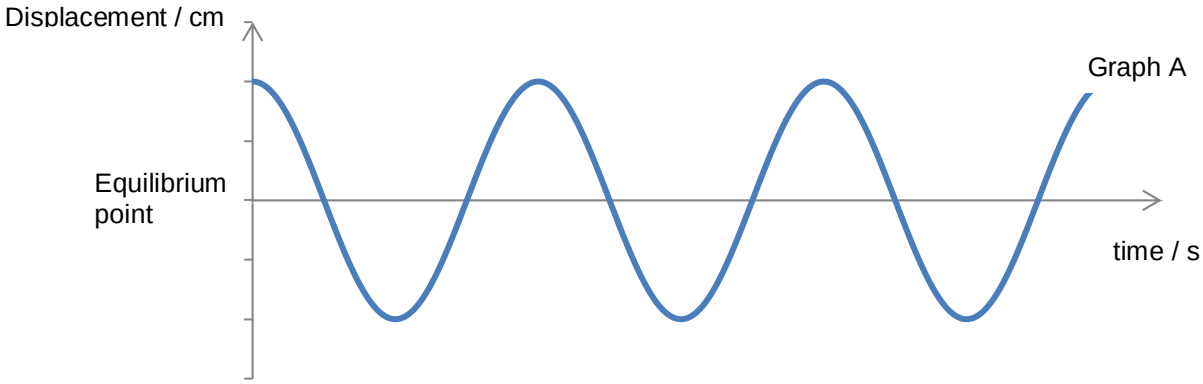


Fig. 7.2

1. When the magnetic field is switched off, the loop oscillates in a simple harmonic motion described by the equation:

$$a = -\frac{k}{M}x$$

where x is the displacement of loop from equilibrium and a is the acceleration of loop

Determine the period, T, of the oscillation.

T = ... s [3]

2. The magnetic field is switched on again.

Sketch in Fig. 7.2, the variation with time of the displacement of the loop. Label the graph B.

[2]

For Examiner's Use

3. The loop is damaged and does not form a closed conducting loop. With the magnetic field still turned on, state and explain the changes, if any, to graph A in Fig 7.2

.....

.....

.....

..... [2]

(b) This part of the question is on transformer.

In the ideal transformer shown in Fig 7.3, the turn ratio $N : N_2$ is 5 : 2, and the source root-mean-square (r.m.s.) voltage, V_s is 80.0 V.

The source resistance, *Rs*, has yet to be determined.

The load resister R_L is 50.0 Ω. A CRO measures the potential difference across the load to be V_{RMS} = 25.0 V

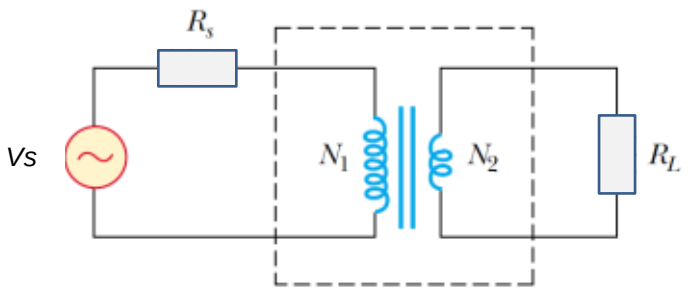


Fig 7.3

(i) Explain why transformers do not work when a steady direct current is used.

.....

.....

..... [2]

(ii) The potential difference across the primary coil of the transformer is *Vp* . The current through the primary coil is *Ip*.

Write an equation relating *Vsource*, *Vp*, *Ip* and *Rs*. [1]

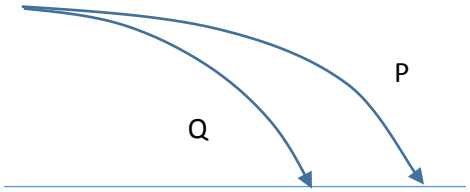
.....

(iii) Hence or otherwise, determine the source resistance, *Rs*.

source resistance, *Rs* = ... Ω [3]

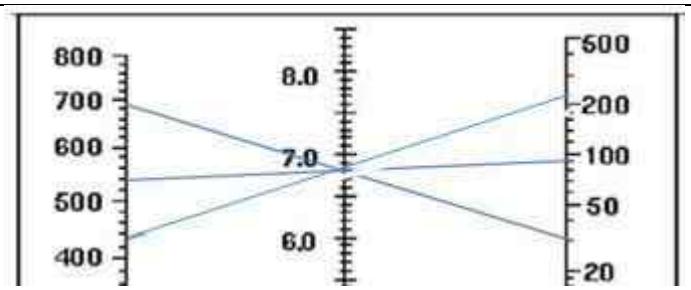
H2 Physics P1

Qn	Ans Key
1	**A**
2	**C**
3	**B**
4	**C**
5	**D**
6	**D**
7	**A**
8	**B**
9	**A**
10	**C**
11	**B**
12	**A**
13	**D**
14	**B**
15	**C**
16	**C**
17	**B**
18	**A**
19	**B**
20	**B**
21	**C**
22	**A**
23	**C**
24	**C**
25	**B**
26	**C**
27	**D**
28	**D**
29	**C**
30	**D**
31	**B**
32	**B**
33	**D**
34	**B**
35	**C**
36	**D**
37	**C**
38	**A**
39	**B**
40	**C**

Qn	
1	
(a)	Applying $v^2 = u^2 + 2as$ in the vertical direction $v^2 = 0 + 2 \times 9.81 \times 80$
	$v = 39.6(1818)$ $= 40 \text{ m s}^{-1}$ (shown)
(b)	$v_y = 39.61818 \text{ m s}^{-1}$
	$v_x = 67 \text{ m s}^{-1}$
	$v = \sqrt{(39.61818^2 + 67^2)}$ $= 77.83701 \text{ m s}^{-1}$ $= 77.8 \text{ m s}^{-1}$
	$\tan \theta = v_y / v_x$ $= 39.61818 / 67$ $\theta = 30.6°$ $= 31°$ below horizontal
(c)	 Horizontal velocity will no longer be constant and decrease with time. Vertical velocity will increase at a slower rate as net acceleration downwards is decreased.
2(a)	Systematic errors are errors that results in the measurements deviating from the true value by a fixed magnitude and direction/ of the same sign and magnitude / with the same magnitude on same side of the true value / having a fixed pattern Random errors are errors that results in the measurements deviating from the of value with no fixed magnitude and direction / of different sign and magnitude on either side of the true value with no fixed magnitude / no fixed pattern.
b(i)	$g = 4\pi^2 \frac{l}{T^2} = 9.869 \text{ m s}^{-2}$
	$\pm\frac{\Delta g}{g} = \pm\left(\frac{\Delta l}{l} + \frac{2\Delta t}{t}\right)$ (or $\left(\frac{\Delta l}{l} + \frac{2\Delta T}{T}\right)$)
	$= \pm\frac{0.1}{98.0} + \frac{2(0.2)}{19.8}$ (or $\frac{0.1}{98.0} + \frac{2(0.02)}{1.98}$) $= \pm 0.021(2)$
	$\pm\Delta g = \pm 0.0212 \times 9.869$ $= \pm 0.21 \, m \, s^{-2}$
	Hence $g = (9.9 \pm 0.2) \, m \, s^{-2}$

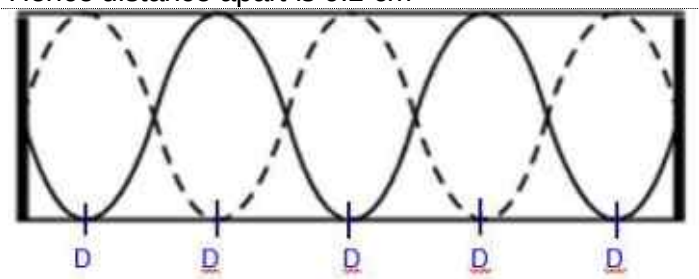
(ii)	$g = (9.9 \pm 0.2) ms^{-2}$ More accurate, less precise $g = (11.15 \pm 0.02) ms^{-2}$ Less accurate, more precise
3	
(a)	Resultant forces zero in all directions Resultant torque / moments zero about any axes / point
b)(i)	Mention the point where moments was taken,
	Clockwise *M* = Anti-clockwise *M* *T*sin70° (0.07) + *W* / 7 (0.03) = *W* (0.11) *T* = 1.60*(713)* *W*
	Resolving forces in the x-direction, R_X = 1.60713 *W* cos70° = 0.54967 *W* *or* Resolving forces in the y-direction, R_Y = *W* + 1.60713 *W* sin70° - *W* / 7 = 2.36735 *W*
	R = $\sqrt{(0.54967\ W)^2 + (2.36735\ W)^2}$ = 2.43(033) *W*
(b)(ii)	When taking moments about the pivot to determine *T*, the moment due to the upward force on the foot is greatly reduced as both the upward force on the foot (due to the cane) and perpendicular distance from the foot to *R* is reduced, leading to a smaller *T* and hence horizontal component of *R*. The reduced upper force on the foot (due to the cane) and smaller *T* also reduced the vertical component of *R*. Therefore *R* is reduced.
4(a)	Sum of the Random vibrational kinetic energy of atoms and Random potential energy between atoms of the iron.
(b)	$W_{on} = 0$, or $\Delta U = mc\Delta\theta$ Decrease in GPE → increase in internal energy $0.6mg\Delta h = mc\Delta\theta$ $\theta_f = \frac{0.6g\Delta h}{c} + 25 = 25.8\ ^oC$
(c)	From (b) Change in temp. is independent of mass or Mass cancels away on both sides of equation
5(a)	When the electrons decelerate, it loses energy, the lost in energy is the energy of the X-ray photons.
	As there is a range of decelerations/energy lost, there is a range of energy of the X-ray photons.
(b)	Energy gain by electron due to accelerating potential = eV
	Electron loses all this energy in the single collision to produce the x-ray photon eV = hc/λ_{min}.

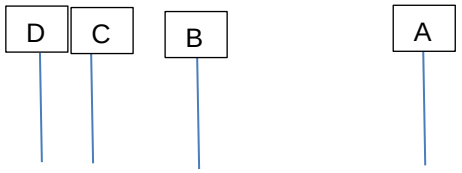
(c)(i)	$h = \frac{1.6 \times 10^{-19} \times 50000 \times 2.50 \times 10^{-11}}{3 \times 10^{8}}$ =6.7 x 10^{-34} J s
(ii)	Suggested Improvement. Vary accelerating potential and observe cutoff wavelength from continuous spectrum.
	Plot λ_{min} vs 1/V Determine *h* from (e/c) gradient
6	
(a)	Minimum freq of em radiation/photon for release of electrons from surface of metal
(b)	E_{MAX} corresponds to electron emitted from surface
	electron (below surface) requires energy to bring it to surface, so less than E_{MAX}
(c)(i)	$\Phi = hc/\lambda_o$
	= 6.63 x 10^{-34} x 3.00 x 10^{8} x 1.85 x 10^{6}
	= 3.68 x 10^{-19} J
(ii)	$1/\lambda$ = 2.5 x 10^{6}, E_{max} = 1.3 x 10^{-19} J
	$\lambda = h/p$
	$= \frac{h}{\sqrt{2mE}}$
	= 1.36 x 10^{-9} m
7	
(a)	LW – oscillations of particles parallel to direction of transfer of energy of wave
	TW – oscillation of particles perpendicular to direction of transfer of energy of waves
(b)	S-waves cannot pass through the liquid outer core as it is a transverse wave and hence cannot cause compression of liquid and hence cannot travel through liquid.
(c)(i)	Akita – 30 mm Pusan – 56 s, 540-550 km, Tokyo – 425-435 km, 210 mm All amplitudes correct Time interval for Pusan correct Distance for Pusan (allow ecf) and Tokyo read correctly
(ii)	Understand must draw 3 circles center at stations All circles drawn with compass and correct scale Epicentre at KOBE
(iii)1.	-Distance from epicenter -Scattering at boundary of different materials, cracks etc. -Absorption due to rocks in Earth Any other suitable answers

	 Magnitude = 6.8
(d)(i) 1.	Ratio = $10^9/10^{6.8}$ = 158
2.	The above shows that a change in magnitude of 2.2 correspond to a change in intensity of about 160 times. Hence using a log scale allows us to compress the scale to more manageable numbers
(ii)	Ratio = $10^{(1.5)(2.2)}$ = 1995 (2000)
(e)	- Population of area - Stricter Building codes – earthquake proof buildings - time information needed to reach residents

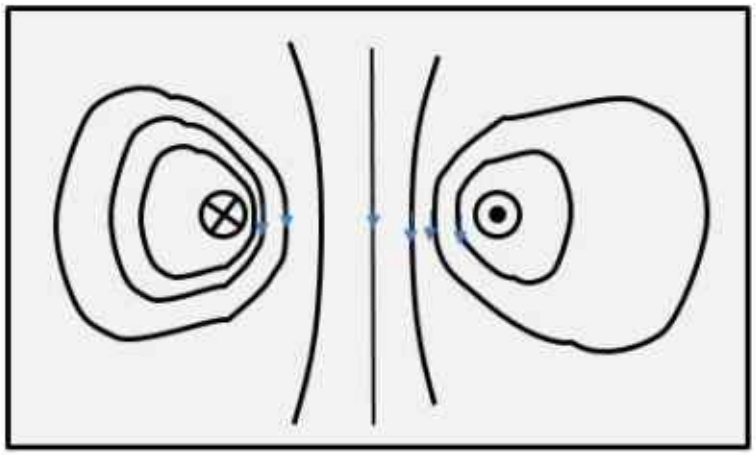
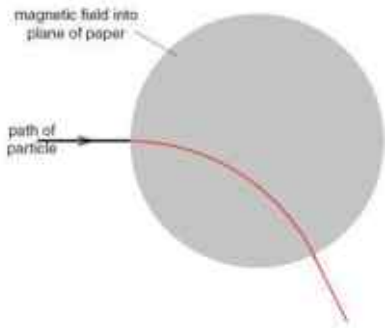
8			
	Basic Procedure (2 marks)		
	Vary *h* and determine *Q* or IV – h; DV - Q	**P1**	
	Explained how *h* is varied by changing position of vertical/larger tube by moving it up or down vertically.	**P2**	**[Max 2]**
	Diagram (1 mark)		
	Labelled diagram of apparatus which includes labelled measuring cylinder/calibrated beaker to receive water or beaker on balance if finding mass	**D1**	**[Max 1]**
	Methods of data collection (2 marks)		
	Explained how Q is determined correctly. Example: *Measuring volume collected from beaker over a given time t with the help of a stopwatch*	**M1**	
	Measure *h* and *l* with a rule/caliper and *d* with a travelling microscope	**M2**	**[Max 2]**
	Analysis (1 marks)		
	Plot a graph of Q against h or lg Q against lg h or any other suitable graph and explained how η is determined.	**A1**	**[Max 1]**
	Example: $\eta = \frac{2\pi\rho g d^4}{l \times gradient}$		
	Safety (1 mark)		**Any 1**
	Reason method to prevent spills, e.g. use tray/sink/cloth on floor.	**S1**	
	Reasoned method to prevent injury when adjusting metal/glass tubes by wearing protective gloves.	**S2**	
	No electrical devices present as water is involved in the experiment	**S3**	**[Max 1]**
	Further detail (3 marks)		**Any 3**
	Repeat experiment for same *h* and average	**F1**	
	Details on measuring *h* to the centre of the horizontal tube e.g. add radius of tube	**F2**	
	Method to measure mass and V and and hence density	**F3**	
	Fill beaker nearly full to reduce %tage uncertainty in measuring of Q	**F4**	
	Determine average *d* or *l* from at least 3 readings from difference position of tube.	**F5**	
	Method to check that tube is horizontal	**F6**	
	Start timing and record V only when water starts flowing out of the narrow tube	**F7**	
	Place Container below wide tube to collect overflow water	**F8**	
	Relationship is valid if straight line passing through origin. (if lg-lg graph, gradient = 1)	**F9**	
	Tap turned on at correct volume to ensure that water overflow to maintained constant *h* when taking readings.	**F10**	**[Max 3]**
	Control (2 marks)		
	stated *l* and *d* are CV by using the same narrow tube.	**C1**	
	Explain how *l* is kept constant "Explain how narrow tube is ensured to be horizontal throughout" Note: If slanted, *l* horizontally will change	**C2**	

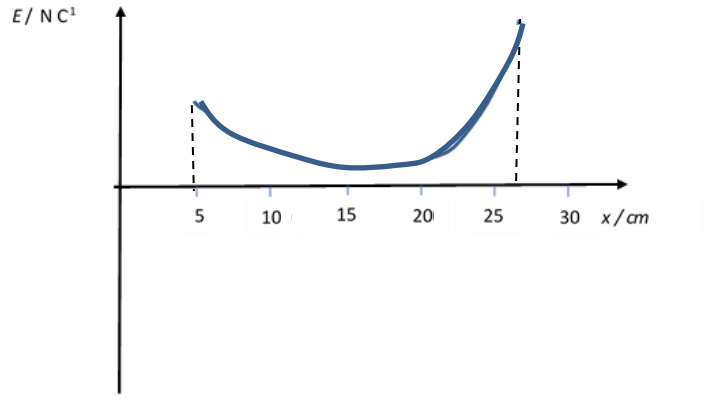
	Explain how ρ is kept constant "Check that temperature of liquid is kept constant for ρ to be constant."	**C3**	**[Max 2]**

Qn	Suggested MS
1(a)	The radian is defined as the angle subtended at the centre of a circle by an arc length equal in length to the radius of the circle. .
1(b)(i)	Weight downwards Normal contact force radially drawn *F* tangential to curvature upwards
(ii)	At constant speed, sum of tangential forces = 0 (Resolve forces tangentially)
(iii)	WD = R x area under *F*-θ graph
(iv)	Determine area under graph correctly (Range 0.9 – 1.1) Or WD by F = gain in GPE = 1.96 J
	WD by F = area x 2 Or since gain in KE = 0
(v)	G = mgR sinθ G starts of 0 and around 2 J at $\pi/2$ (1.57)
	K is constant at 0.20 J
2	
(a)	There are standing waves produced in the microwave oven during the cooking process because incident wave from the left gets reflected by the reflective wall on the right and they superimpose /overlap /interfere
	The conditions must be right such that the distance between the source and wall must be integral multiples of half the wavelength of the microwave.to form standing wave (*with nodes at the ends*.)
	as they have the same speed, frequency and *(almost*) the same amplitude (follows any of the M1 mark)
(b)(i)	Intensity of the microwave is strongest (largest amplitudes) at the antinodes, hence the dry regions are the regions of antinodes
	Wavelength = $3.0 \times 10^8 / 2.45 \times 10^9$
	= 0.1224 m = 12.2 cm
	Hence distance apart is 6.1 cm
(ii)	
(c)	*So there are regions in the oven where the microwave has high amplitude (antinodes) and there are region where the microwave has no displacement (node). Thus ants can stay away from the regions of high amplitude which has high heat and thus stay alive*.
	Understand that the ants will stay away from the position of antinodes / continuously move to positions of nodes to stay alive.

(d)	The turntable enables different parts of the food to move to the antinodes of the standing wave and get heated up. Thus it helps heat up the food more uniformly.
3(a)	Amount of electrical energy converted to heat and light
	per unit charge / when unit charge flow across the bulb
(b)	Bulb in 1 can be fully switched off.
	In 2, there is always pd across bulb/ there is always current through bulb (or equivalent)
(c)	Diagram with a switch in the appropriate location of the circuit.
	switch
(d)(i)	$R = \frac{V^2}{P} = \frac{240^2}{60}$ $= 960\,\Omega$
(ii)	Resistance lower since Room temperature lower than working temperature
	Rate of lattice vibration lower
4 (ai)	
	Energy levels occupied by Electrons in the atom are discrete. When electrons transit from a higher energy level to a lower energy level, it emit photons of energy that corresponds to energy difference between the 2 discrete energy levels.
	Thus only particular frequencies are emitted/observed since E = hf
(aii)	Atoms (*or electrons*) are in high energy states so either gas at a high temperature or high voltage applied across it.
	Gaseous state to be sufficiently far apart.
(b)(i)	$8.68 \times 1.60 \times 10^{-19} = 1.39 \times 10^{-18} J$. This is ionization energy.
(ii)	D, since it has the largest energy
(iii)	$\lambda = \frac{hc}{(-0.67 - (5.73))(1.60 \times 10^{-19})} = 245\,nm$
(iv)	UV
(d)	
	Order of lines correct (at least A or D labelled and Spacing roughly as shown
(f)	In a metal, the electrons are delocalized compared to the electrons in an isolated atom that are attracted to the nucleus. Hence ionization energy which is the energy need to remove the electron from the atom is different from Work function energy
5	
(a)	A high ratio of protons to neutrons would make the nucleus unstable due to the repulsive nature of the electrostatic force between protons.
(b)	Alpha decay causes a loss of 4 nucleons while beta decay has no effect on the number of nucleons

(c)	Total initial momentum = total final momentum of a <u>system</u> provided there is no net external force acting on the system.
(d) (i)	$^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He + energy$
(d)(ii)	Energy released = $(m_{Rn} - (m_{Po} + m_{He}))c^2$
	= (222.1706 – (218.0090 + 4.0026)) x $1.66 \times 10^{-27} \times (3.00 \times 10^{8})^2$
	= 8.964×10^{-13} J
(d)(iii)	By COM, total *p* initial = total *p* final $m_{Rn}(0) = m_{Po} v_{Po} + m_{He} v_{He}$
	$m_{Po} v_{Po} = - m_{He} v_{He}$
	$KE = \frac{1}{2} m v^2 = p^2 / 2m$
	$\frac{\text{KE of } \alpha \text{ particle}}{\text{KE of Po nucleus}} = \frac{\frac{p_{\alpha}^2}{2m_{\alpha}}}{\frac{p_{Po}^2}{2m_{Po}}}$
	$= \frac{m_{po}}{m_{\alpha}}$
	$= \frac{218}{4}$
(d)(iv)	*KE* of α particle = (218 / (218 + 4)) x 8.964×10^{-13} $\frac{1}{2}(4 \times 1.66 \times 10^{-27}) v^2 = (218 / 222) \times 8.964 \times 10^{-13}$ $v = 1.63\ (1.62830) \times 10^{7}$ m s^{-1}
(e)(i)	Range of KE of *β* particles produced For energy to be conserved, there must be another particle / wave (neutrino) that accounts for the remaining energy produced
(e)(ii)	Student is correct if anti-neutrino is emitted along the same axis as the *At* nucleus and *β* particle so that linear momentum can be conserved in <u>all directions</u>. OR Student is wrong as there should be an angle between the paths of the *At* nucleus and *β* particle because the anti-neutrino is also emitted so that linear momentum can be conserved in <u>all directions</u>.
6(a)	
(i)	Gravitational
(ii)	Gravitational and Electric Field
(iii)	Magnetic

	Gravitational and Electric
(b)(i)	B-field is a region of space where a charge moving not parallel to the field or conductor carrying a current not placed parallel to the field or a magnetic object experience a magnetic force.
	Region of space with one correct example stated
	With at least a correct 2nd example
(ii)	S-pole of a magnet
(iii)	
	
(c)	
(i)	Force is always constant
	and always normal to motion of charged particle
	Hence provides the centripetal force
(ii)	
(d)	
(i)	WD by an external agent on a small positive point test charge per unit charge
	To bring the charge from infinity to the point.
(ii)1.	$V_A + V_B = 0$ at x = 18 cm.
	$(3.6 \times 10^{-9}) / (4\pi\varepsilon_o \times 18 \times 10^{-2})$ $+ q / (4\pi\varepsilon_o \times 12 \times 10^{-2}) = 0$
	$q = -2.4 \times 10^{-9}$ C
(ii)2	

	
7(a)(i) 1	Explained why induced current present
	Explained why magnetic force on bottom edge and not on top edge
(i)(2)	1. constant speed, forces on loop $BIw = mg,$ 2. By definition $I = \frac{\epsilon}{R}$, 3. By Faraday's Law $\epsilon = Bwv_t$ 1,2,3 gives $v_t = \frac{MgR}{B^2w^2}$
(i)(3)	When R increases, induced current drops Induced/resistive force drops Higher v_t
(ii)1	$\omega^2 = \frac{k}{m}$ $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.5}{12.5}}$ *T*=1.26 s
(ii)2	Light damping/moderate dampling: Amplitude decreases gradually; *T* ~ unchanged / increases
(ii)3	No induced current No damping / resistive force /no loss of energy
(b)(i)	When steady dc used, the magnetic field from primary remains a constant, hence no change in flux linkage (*experienced in the core*.) Hence no induced emf experienced by secondary coil
(ii)	$V_s = I_p\, R_s + V_p$
(iii)	Turn ratio: $\frac{N_p}{N_s} = \frac{V_p}{V_{sec}} = \frac{5}{2}$, $V_p = \frac{5}{2} \times 25\, V = 62.5\, V$ Energy transferred via transformer: $62.5\ \times I_p = 25 \times \frac{1}{2}, I_p = 0.20$ Hence $80 = 0.20R_s + 62.5$

Candidate Name _____ ( ) PDG

ANDERSON JUNIOR COLLEGE

2016 JC2 Preliminary Examination

PHYSICS 9646/02

Higher 2

Paper 2 Structured Questions **Tuesday 13 September 2016**

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name** and **PDG** 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 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	
Deduction	
Total	

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}

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, $\phi = -G\frac{m}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$v = \pm \omega \sqrt{(x_0^2 - x^2)}$

mean kinetic energy of a molecule of an ideal gas, $E = \frac{3}{2}kT$

resistors in series, $R = R_1 + R_2 + \ldots$

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, $x = x_0 \sin \omega t$

transmission coefficient, $T \propto exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 exp(-\lambda t)$

decay constant. $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** Explain what is meant by an *electric field of force*.

……

……

……[1]

(b) Fig. 1.1 shows two vertical plates A and B whose electric potentials are 60.0 V and –30.0 V respectively.

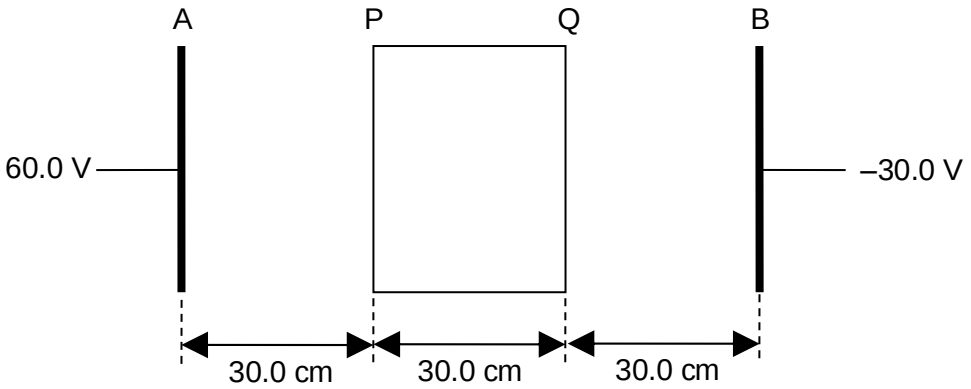


Fig. 1.1

The plates are 90.0 cm apart. A conductor of thickness 30.0 cm is situated centrally between the two plates.

(i) On Fig. 1.2, sketch the variation of electric potential V with distance x between the two plates.

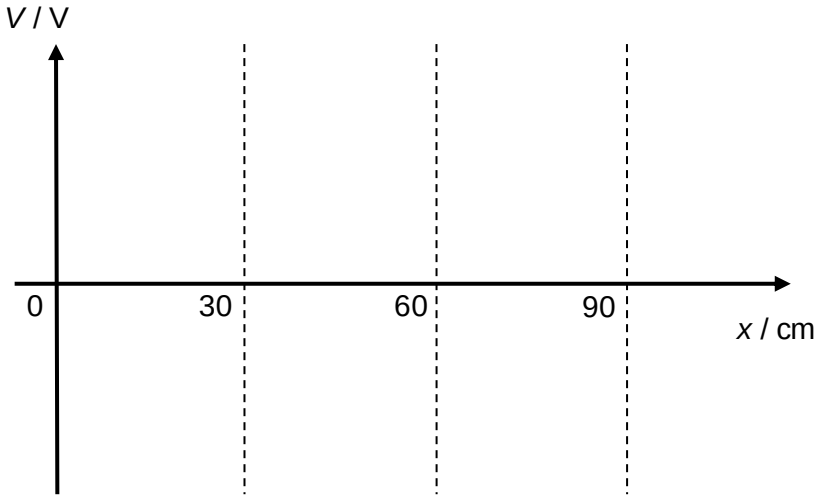


Fig. 1.2 [2]

(ii) On Fig. 1.3, sketch the variation of electric field strength E with distance x between the two plates.

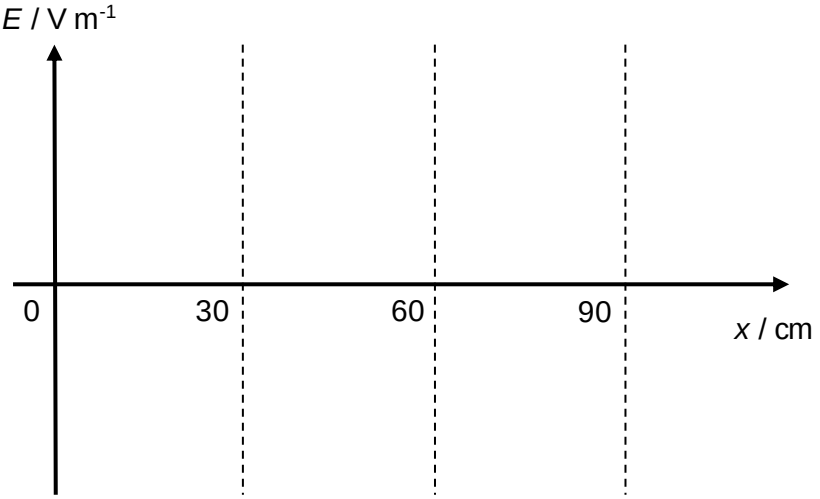


Fig. 1.3 [1]

(c) The thickness of the conductor is increased. State and explain how the electric field strength between the plates A and B will change.

region AP :

……..

……..

……..

region PQ :

……..

……..

……..[3]

(d) Fig. 1.4 shows a beta particle projected vertically downward with an initial velocity *u* between the two vertical plates A and B. The length of the plates is 20.0 cm.

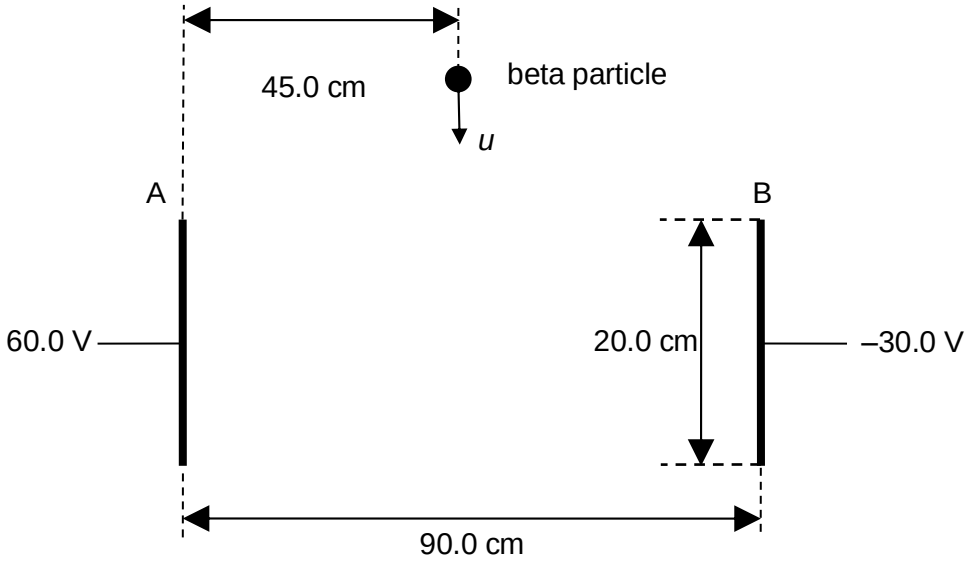


Fig. 1.4

Ignoring the effects due to gravity,

(i) describe the path travelled by the charged particle between the two plates A and B,

……

…… [1]

(ii) calculate the maximum initial velocity *u* so that the charged particle will be able to hit one of the plates.

u = ……m s^{-1} [3]

2 **(a)** Two inclined planes RA and LA each have the same constant gradient. They meet at their lower edges, as shown in Fig. 2.1.

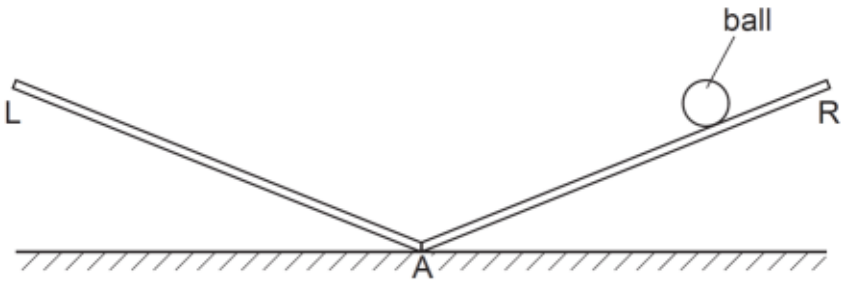


Fig. 2.1

A small ball moves from rest down plane RA and then rises up plane LA. It then moves down plane LA and rises up plane RA to its original height. The motion repeats itself.

State and explain whether the motion of the ball is simple harmonic.

.....

.....

.....[2]

(b) A small ball rests at point P on a curved track of radius *r*, as shown in Fig. 2.2.

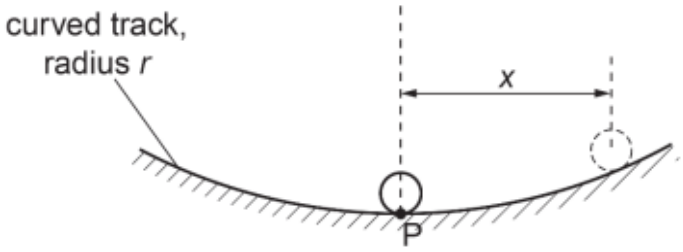


Fig. 2.2

The ball is moved a small distance to one side and is then released. The horizontal displacement *x* of the ball is related to its acceleration *a* towards P by the expression

$$a = -\frac{gx}{r}$$

where *g* is the acceleration of free fall.

(i) Show that the ball undergoes simple harmonic motion.

.....

.....

.....

..... [2]

(i) The radius r of curvature of the track is 28 cm.

Determine the time interval τ between the ball passing point P and then returning to point P.

τ = ... s [2]

(c) The variation with time t of the displacement x of the ball in **(b)** is shown in Fig. 2.3.

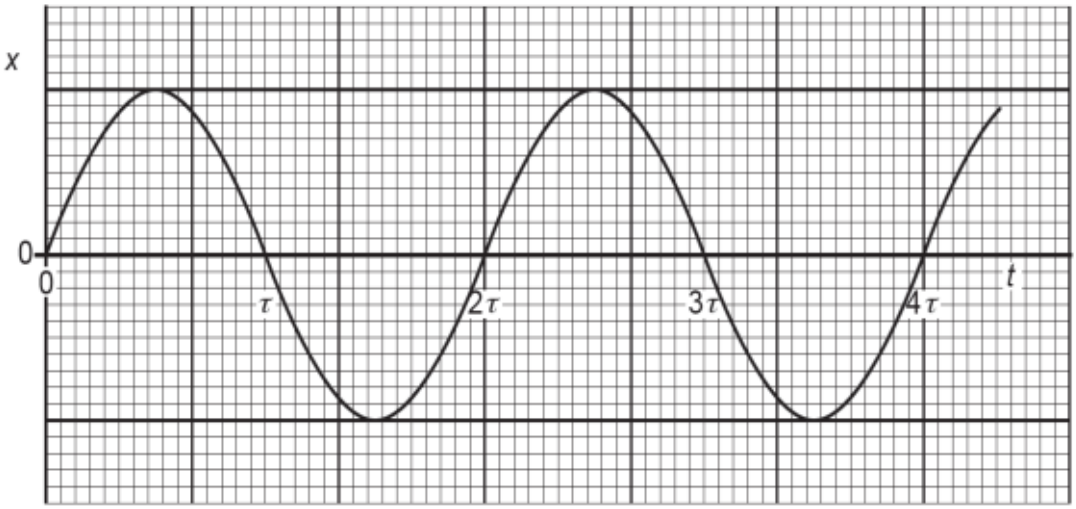


Fig. 2.3

Some moisture now forms on the track, causing the ball to come to rest after approximately 15 oscillations.

On the axes of Fig. 2.3, sketch the variation with time t of the displacement x of the ball for the first two periods after the moisture has formed. Assume the moisture forms at time $t = 0$. [3]

3 Two cylinders A and B are connected by a tube of negligible volume, as shown in Fig. 3.1.

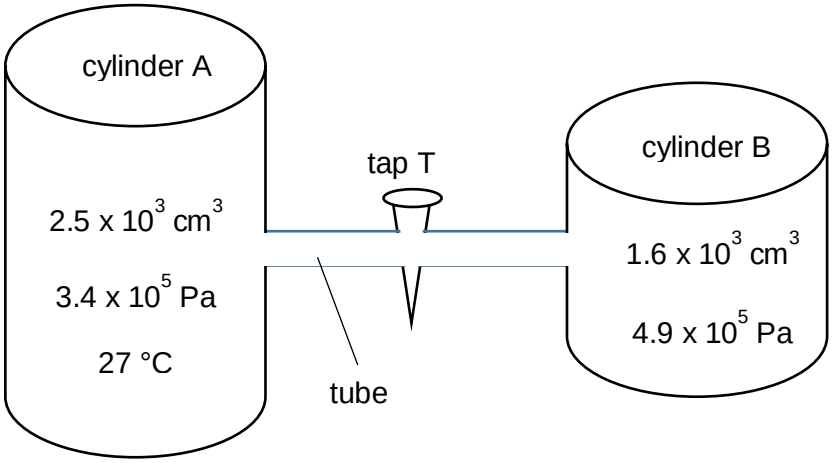


Fig. 3.1

Initially, tap T is closed. The cylinders contain an ideal gas at different pressures.
Cylinder A has a constant volume of 2.5×10^3 cm^3 and contains gas at pressure 3.4×10^5 Pa and temperature of 27 °C.
Cylinder B has a constant volume of 1.6×10^3 cm^3 and initially contains 0.20 mol of gas at pressure 4.9×10^5 Pa.

(a) Explain what is meant by an *ideal gas*.

……..

……..[1]

(b) When tap T is opened, the pressure of the gas in both cylinders is 4.0×10^5 Pa.
No thermal energy enters or leaves the gas.

Determine the final temperature of the gas.

temperature = …… K [3]

(c) State and explain the effect on the internal energy of the gas with the opening of the tap.

……..

……..

……..

……..[2]

4 **(a)** A 2.0 cm square copper frame is moving on a smooth surface with a constant speed of 1.0 cm s^{-1} towards two uniform magnetic fields, as shown in Fig. 4.1.

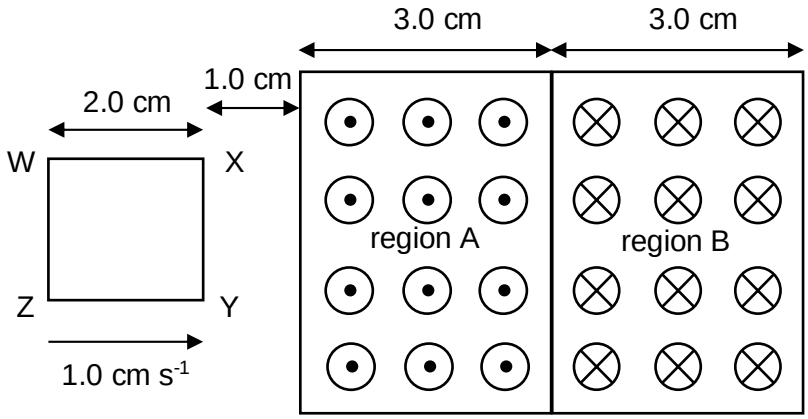


Fig. 4.1

An external force *F* is applied on the frame when necessary to ensure that the frame moves at a constant speed. The position of the frame in Fig. 4.1 is taken to be at $t = 0$ s.

The magnetic field in region A is directed out of the paper while the magnetic field in region B is directed into the paper. The magnetic flux density of both fields is 1.0 T. The resistance of the frame is 8.0×10^{-4} Ω.

A short instant later, the side XY of the frame enters region A.

(i) Explain why an external force *F* is necessary to maintain the constant speed of the frame as it enters region A.

.....

.....

.....

.....

.....[3]

(ii) Determine the magnitude of the external force F at this instant.

F = …….. N [3]

(b) On Fig. 4.2, sketch the variation of external force F with time t, from t = 0 s till the frame completely emerges from region B. The graph for region A has been drawn. Values on F axis are not required.

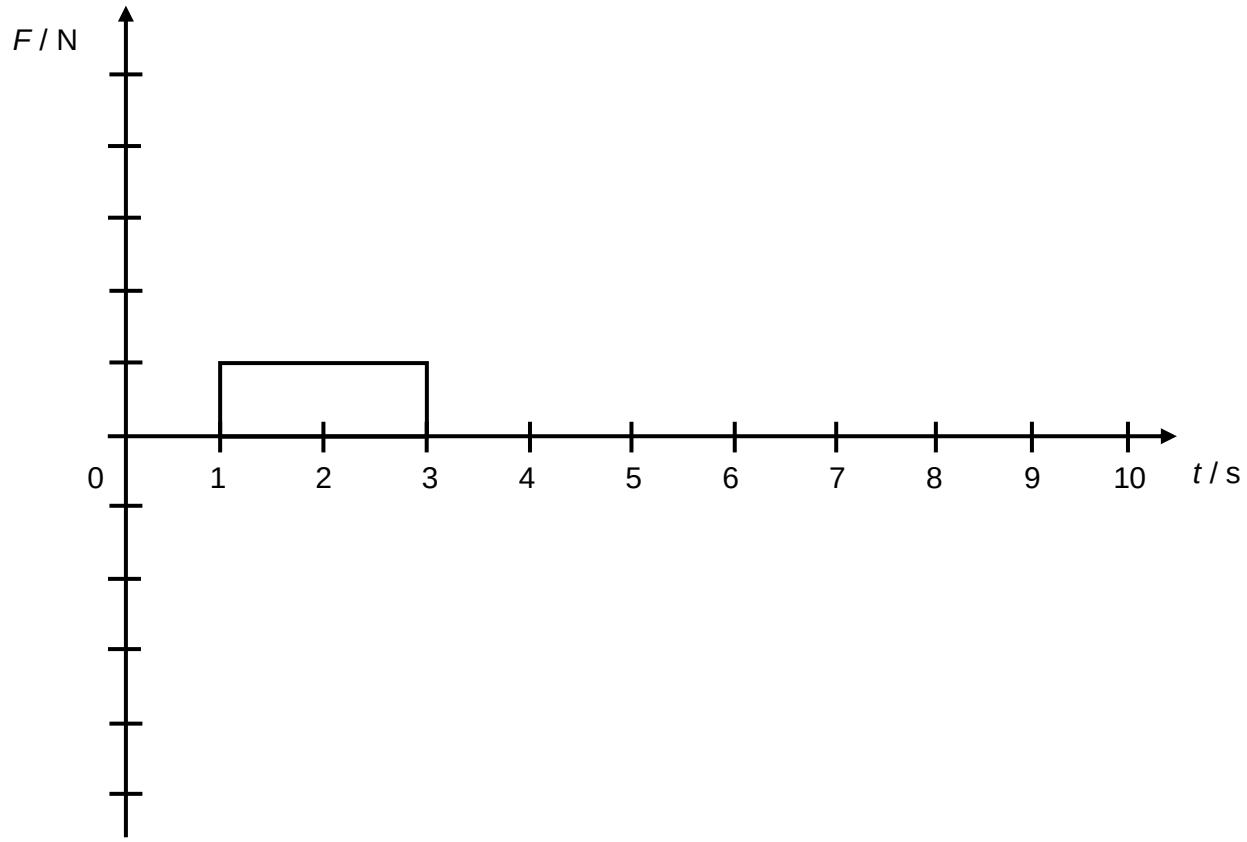


Fig. 4.2 [2]

5 **(a)** An emission spectrum is seen as a series of differently coloured lines on a black background.

Suggest how this observation provides evidence for discrete electron energy levels in atoms.

……

……

……

……[2]

(b) Fig. 5.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	photon energy / 10^{-19} J
656	3.03
486	……
1880	1.06

Fig. 5.1

(i) Complete Fig. 5.1 by calculating the photon energy for the wavelength of 486 nm.

[1]

(ii) Fig. 5.2 is a partially completed diagram to show energy levels of a hydrogen atom.

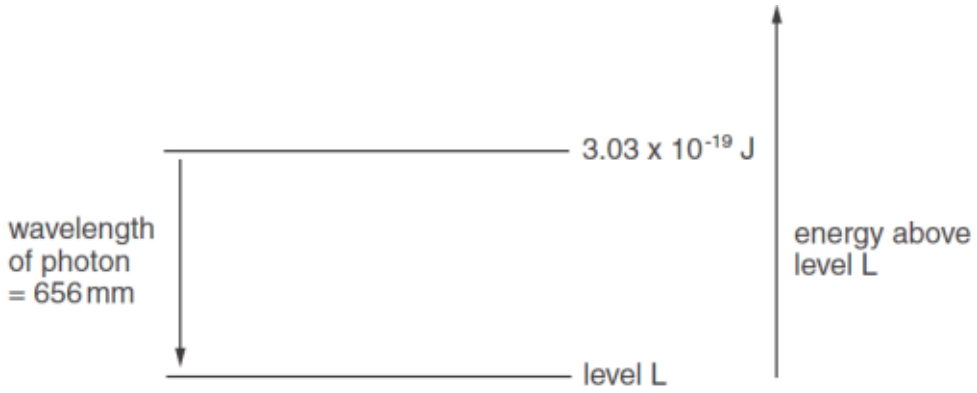


Fig. 5.2

On Fig. 5.2 draw one further labelled energy level, and complete the diagram with arrows to show the energy changes for the other two wavelengths. [3]

(c) In a ruby laser, a flash lamp which produces a broad spectrum of light is used to optically pump the chromium atoms in the ruby crystal from E_0 to E_2, as shown in Fig. 5.3. Lasing takes place between E_1 and E_0.

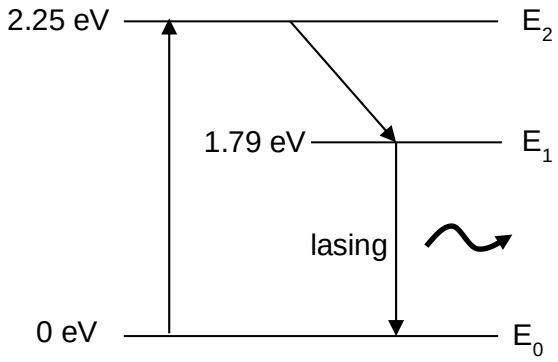


Fig. 5.3

(i) Explain what is meant by *stimulated emission.*

……

……

…… [2]

(ii) Explain why it is not advantageous for E_2 to be a metastable state.

……

……

…… [2]

(iii) Referring to Fig. 5.3, determine the frequency of the radiation generated due to spontaneous emission.

frequency = ……Hz [1]

6 A small boat is powered by an outboard motor of variable power P. Fig. 6.1 shows the variation with speed v of P when the boat is carrying different total mass, m.

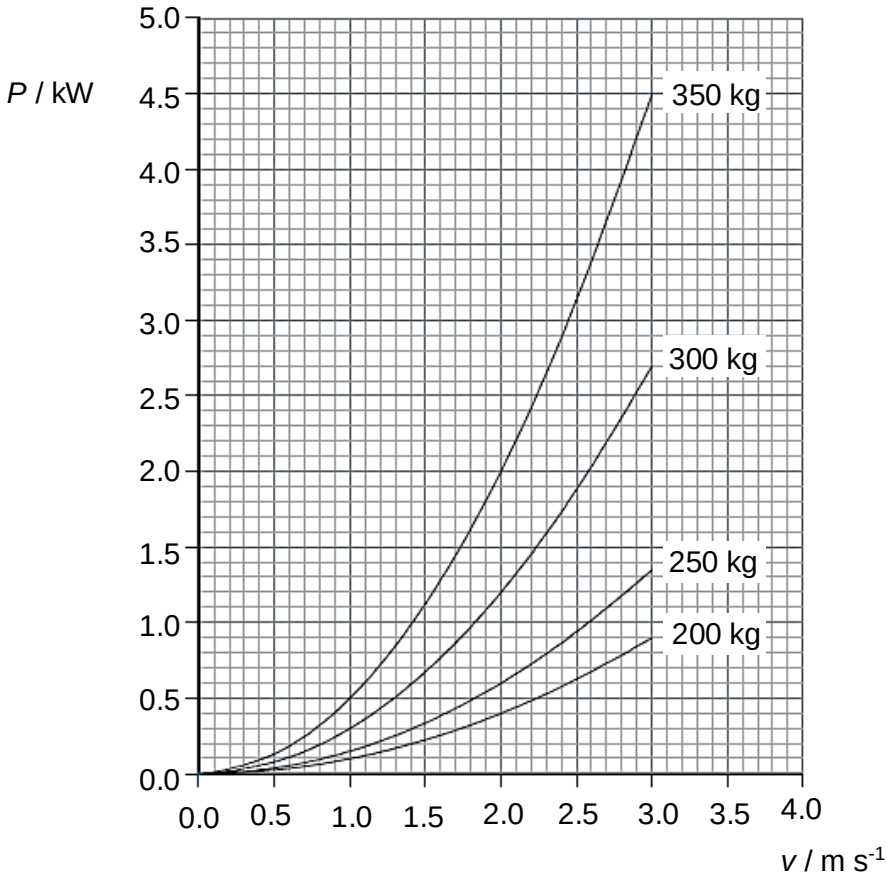


Fig. 6.1

(a) A student thinks that the power P is proportional to the total mass m for a speed of 2.5 m s^{-1}. Show, without drawing a graph, that this proposal is **not** correct.

[2]

(b) Fig. 6.2 shows some of the data for v, ln (P / kW) and ln (v / m s^{-1}) for a boat of total mass 350 kg.

v / m s^{-1}	ln (P / kW)	ln (v / m s^{-1})
0.5		
1.0	– 0.69	0.00
1.5	0.10	0.41
2.0	0.69	0.69
2.5	1.15	0.92
3.0	1.50	1.10

Fig. 6.2

(i) Complete Fig. 6.2 for the speed of 0.5 m s^{-1}. [1]

(ii) Fig. 6.3 is a graph of some of the data in Fig. 6.2.

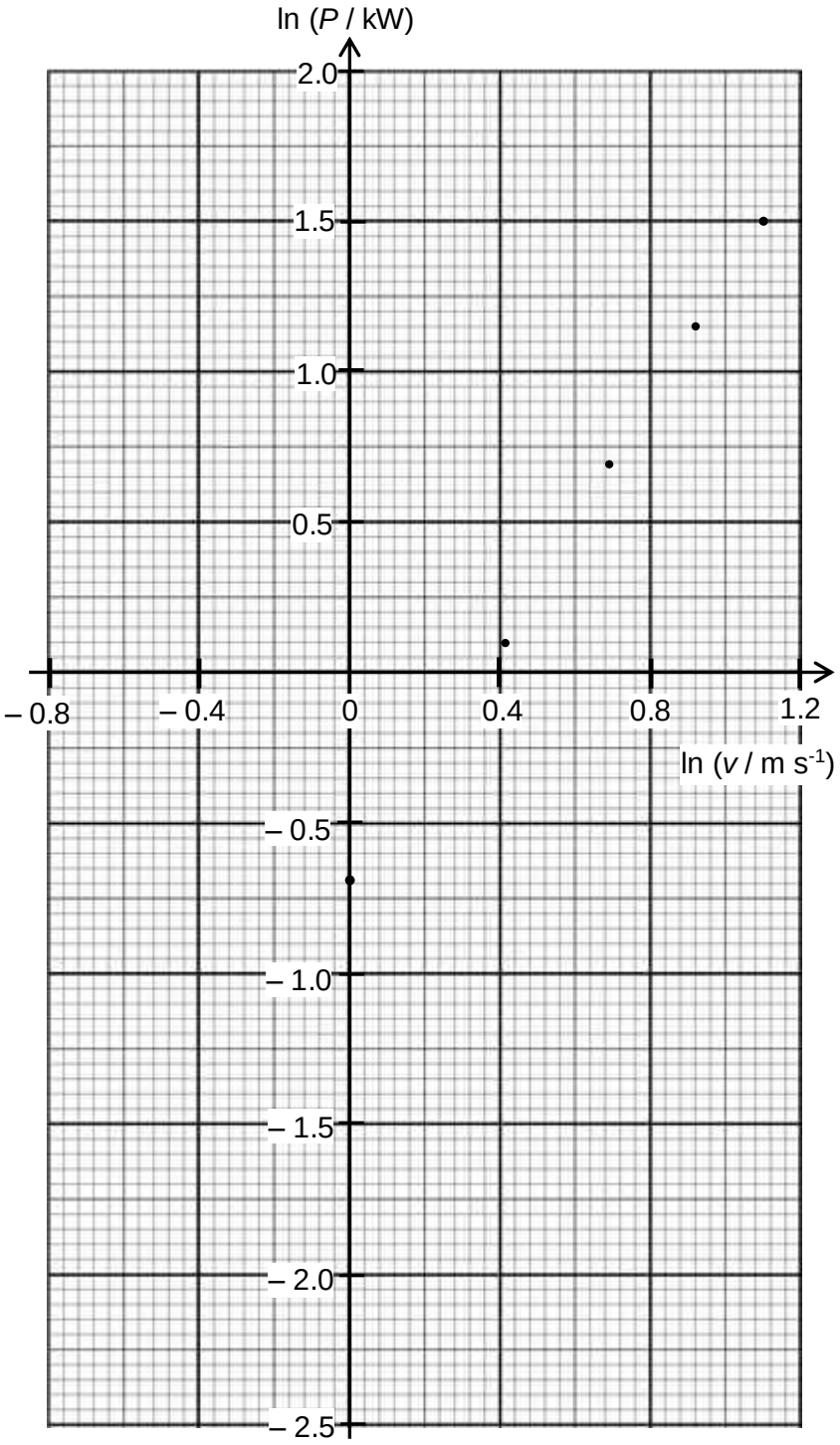


Fig. 6.3

Complete Fig. 6.3 using your data for the speed of 0.5 m s^{-1}. [1]

(iii) It is proposed that the power P changes with speed v according to the expression

$$P = kv^n$$

where k is a constant and n is an integer.

Explain why the graph of Fig. 6.3 supports this proposal.

……..

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…….. [2]

(iv) Use Fig. 6.3 to determine the value of the integer n.

n = …… [3]

(c) Determine the drag force acting on the boat of total mass 300 kg and travelling at a steady speed of 2.5 m s^{-1}. Show clear explanations in your working.

drag force = …… N [3]

(d) At the steady speed of 2.5 m s^{-1} and with a total mass of 300 kg, the outboard motor consumes diesel fuel at a rate of 1.1 litres / hour. The energy density for the diesel fuel used is 32 MJ per litre.

Calculate the efficiency of the outboard motor with the boat of total mass 300 kg travelling at the speed of 2.5 m s^{-1}.

efficiency = …… [3]

7 Scientists had measured the speed of a tsunami to be about 480 km h^{-1}. The waves slowed down as they approached the shore where the energy of the waves was used to increase their height and shear force as they approached the shore.

Theory suggests that the relation between the speed of transverse water waves v and the depth of water d is

$$v = k\, d^{\,n}$$

where k and n are constants.

You are provided with a vibrator that can generate mechanical water waves in a ripple tank. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of n for water waves in a ripple tank.

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 speed of the waves would be determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

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ANDERSON JUNIOR COLLEGE

2016 JC2 Preliminary Examination

PHYSICS Higher 2 9646/01

Paper 1 Multiple Choice **Friday 23 September 2016**

1 hour 15 minutes

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, class index number and PDG in the spaces provided above.

Write your name and PDG on the Answer Sheet.
Shade and write your NRIC/FIN.

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 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.

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

Data

speed of light in free space, $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$

permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$

permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$

$(1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$

elementary charge, $e = 1.60 \times 10^{-19}\ \text{C}$

the Planck constant, $h = 6.63 \times 10^{-34}\ \text{J s}$

unified atomic mass constant, $u = 1.66 \times 10^{-27}\ \text{kg}$

rest mass of electron, $m_e = 9.11 \times 10^{-31}\ \text{kg}$

rest mass of proton, $m_p = 1.67 \times 10^{-27}\ \text{kg}$

molar gas constant, $R = 8.31\ \text{J K}^{-1}\text{mol}^{-1}$

the Avogadro constant, $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

the Boltzmann constant, $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$

gravitational constant, $G = 6.67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2}$

acceleration of free fall, $g = 9.81\ \text{m s}^{-2}$

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, $\phi = -\frac{Gm}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$v = \pm \omega \sqrt{x_0^2 - x^2}$

mean kinetic energy of a molecule of an ideal gas, $E = \frac{3}{2}kT$

resistors in series, $R = R_1 + R_2 + \ldots$

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, $x = x_0 \sin \omega t$

transmission coefficient, $T \propto exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

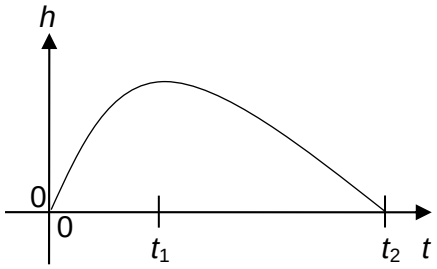
radioactive decay, $x = x_0 exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 Two forces of 4.0 N and 6.0 N act at a point. Which one of the following could **not** be the magnitude of their resultant?

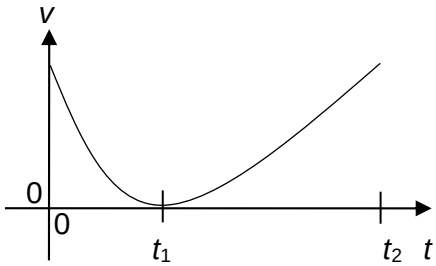
A 1.0 N **B** 4.0 N **C** 6.0 N **D** 9.8 N

2 A ball is thrown vertically upwards and returns along the same path. The graph shows how its height *h* above the ground varies with time *t*.

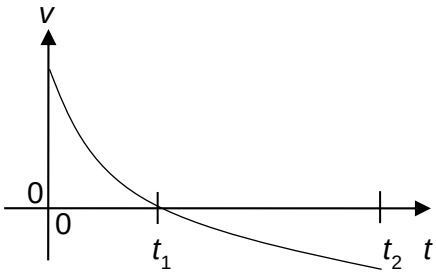


Which graph shows the variation with time *t* of the velocity *v* of the ball?

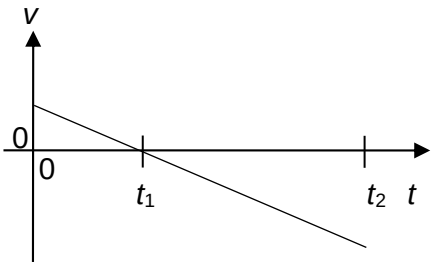
A



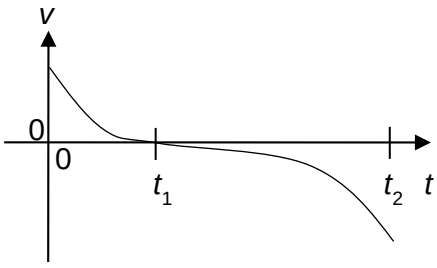
B



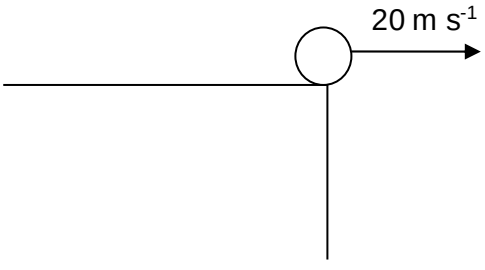
C



D



3 A ball is projected horizontally from a cliff with a velocity of 20 m s^{-1}. Air resistance is negligible.



What is the time when its vertical component of velocity is twice that of its horizontal component?

A 1.0 s **B** 2.0 s **C** 4.1 s **D** 9.8 s

4 A man of mass 70 kg is standing in a lift descending with a deceleration of 0.20 m s^{-2}.

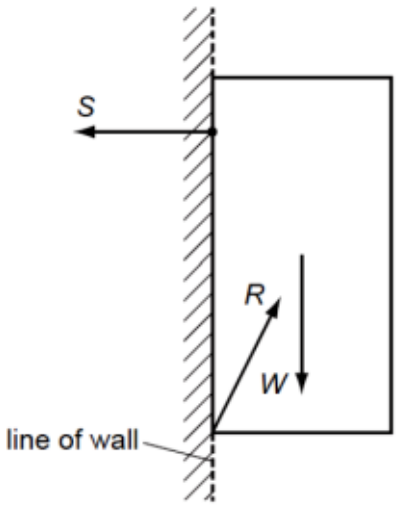
What is the force exerted on the man's feet by the floor?

A 140 N **B** 670 N **C** 690 N **D** 700 N

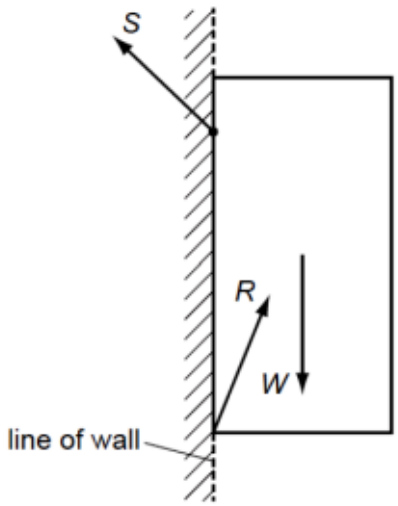
5 A cupboard is attached to a wall by a screw.

Which force diagram shows the cupboard in equilibrium, with the weight *W* of the cupboard, the force *S* that the screw exerts on the cupboard and the force *R* that the wall exerts on the cupboard?

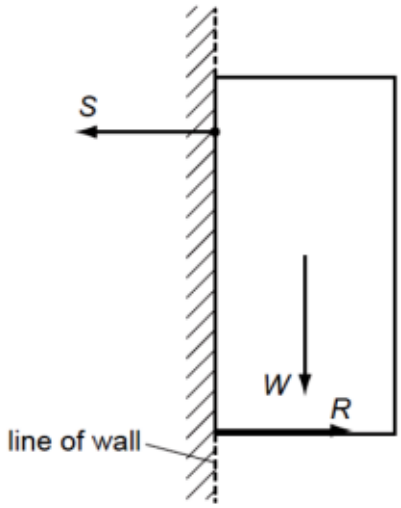
A



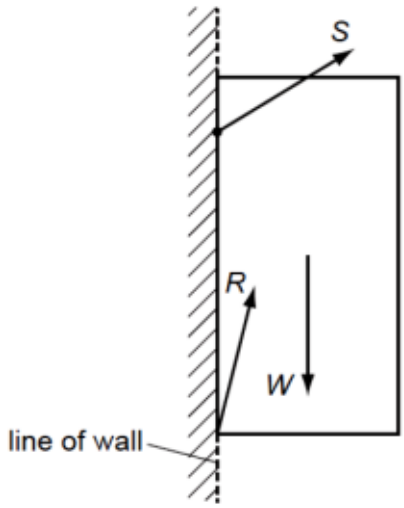
B



C



D

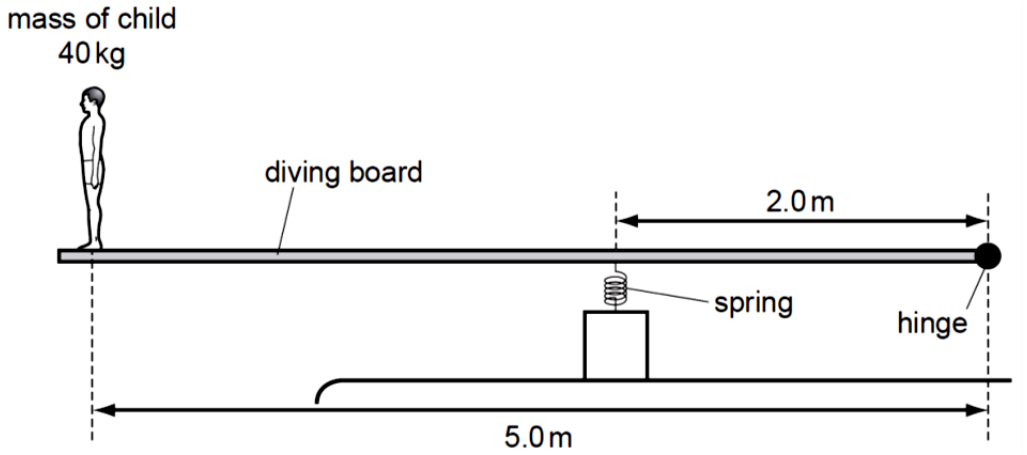


6 A ball of mass 300 g is moving on a smooth table horizontally with a speed of 10 m s^{-1}. It continues to travel and falls off from its edge. The falling ball then enters a stationary cart of mass 1.2 kg at an angle of 30° below the horizontal. After the ball lands into the cart, the cart immediately moves off with the ball horizontally at a particular speed. Air resistance is considered to be negligible.

What is the final kinetic energy of the ball and cart?

A 0 J **B** 2.2 J **C** 3.0 J **D** 25 J

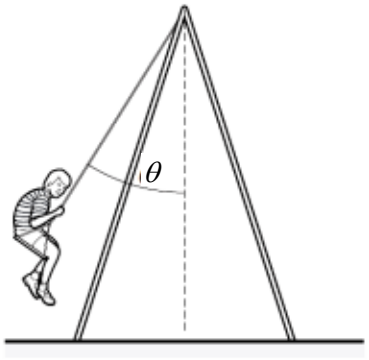
7 A diving board of length 5.0 m is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.



What is the extra compression of the spring caused by the child standing on the end of the board?

A 1.0 cm **B** 1.6 cm **C** 9.8 cm **D** 16 cm

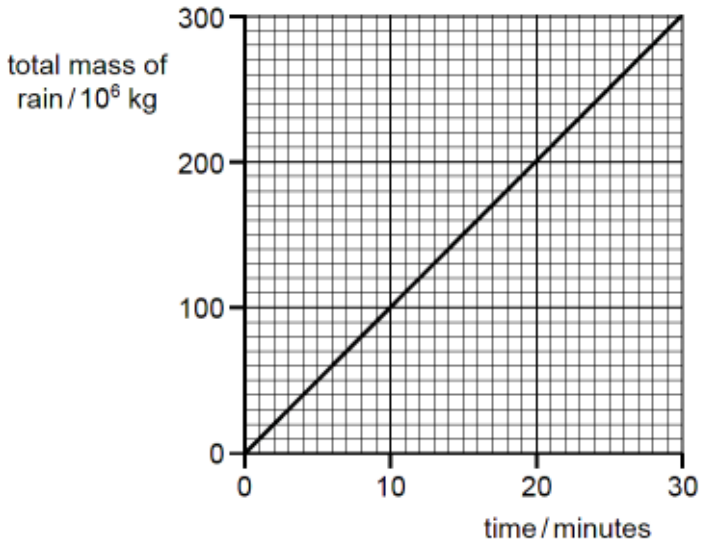
8 A child of mass 50 kg is on a swing which is suspended by 4.0 m ropes from a rigid support. The horizontal speed of the swing as it passes through the lowest point is 3.0 m s^{-1}.



What is the angle θ that the rope makes with the vertical when the swing is at its highest point?

A 28° **B** 40° **C** 42° **D** 62°

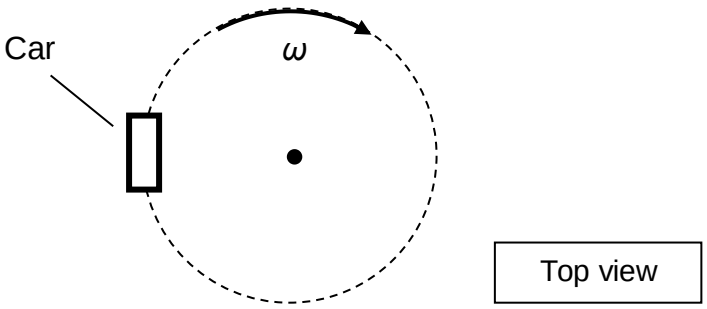
9 Rain from a thunderstorm reaches the ground at a speed of 12 m s^{-1}. The graph shows how the total mass of deposited rain increases with time.



What is the average power delivered by the rain as it hits the ground?

A 1.0 x 10^6 W **B** 1.2 x 10^7 W **C** 2.4 x 10^7 W **D** 7.2 x 10^8 W

10 A car moves around a horizontal circular track at a constant angular speed ω.



Which of the following statements is true about the car's motion?

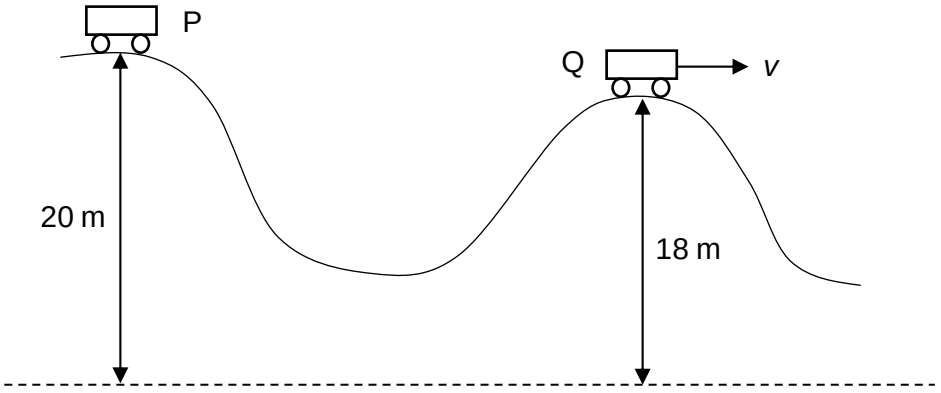
A Its linear velocity is constant.

B Its linear acceleration is constant.

C Its linear acceleration is zero.

D Its linear velocity is changing.

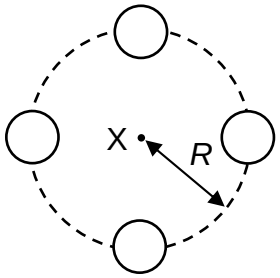
11 In a frictionless roller coaster ride a car of mass 150 kg starts from rest at point P of height 20 m and reaches point Q of height 18 m with speed v. The radius of curvature of the hill at point Q is 9.0 m.



What is the magnitude of the force by the car on the hill when it reaches point Q?

A 320 N **B** 410 N **C** 650 N **D** 820 N

12 Four bodies of equal mass M are equally spaced in a circle of radius R with its center at X.



Which of the following statements is true?

A The net gravitational potential at X is minimum.

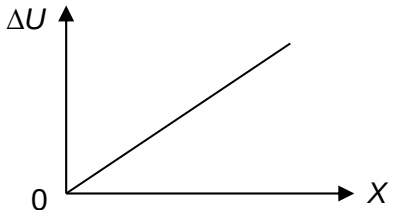
B The net force acting on any of the bodies is the same.

C The net gravitational field strength is non-zero at X.

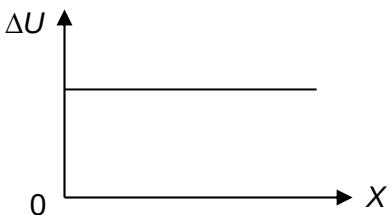
D The net acceleration on any body is directed towards X.

13 Which of the following graphs best illustrates the variation with the height x above the surface of the Earth of the change in gravitational potential energy ΔU of a spacecraft during the initial few hundred metres after launch?

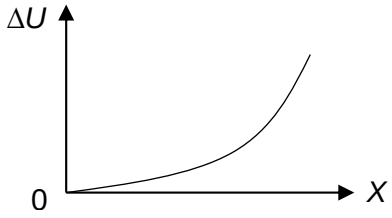
A



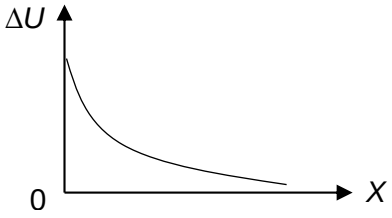
B



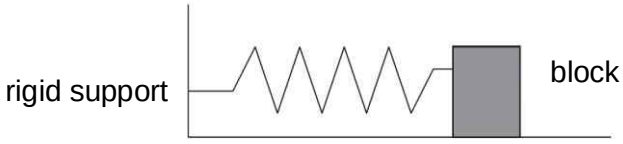
C



D



14 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.

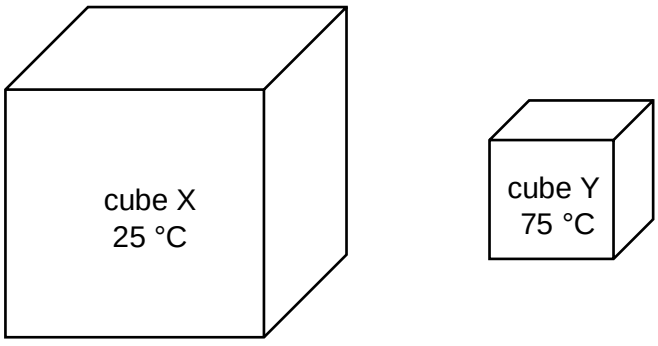
For an initial displacement of $\frac{X}{2}$ which of the following is the best estimate for the period of oscillations and the total energy of the system?

	Period	Total energy
A	T	$\frac{E}{4}$
B	T	$\frac{E}{2}$
C	$\frac{T}{2}$	$\frac{E}{4}$
D	$\frac{T}{2}$	$\frac{E}{2}$

15 The ionosphere contains free electrons. What is the amplitude of oscillations of these electrons when subject to a 200 kHz electromagnetic wave in which the oscillations of electric field have amplitude 5.0×10^{-3} V m^{-1} ?

A 5.6×10^{-4} m **B** 2.5×10^{-8} m **C** 4.0×10^{-9} m **D** 3.2×10^{-15} m

16 Two cubes X and Y are both made of iron. The area of each side of cube X is twice that of cube Y.

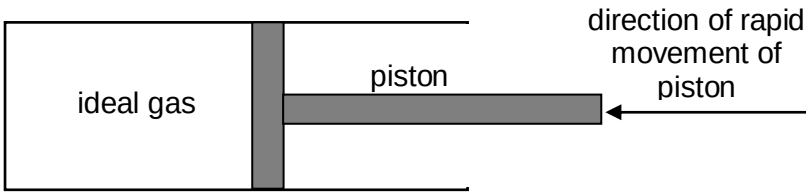


Initially, cube X is at 25 °C and cube Y is at 75 °C.
The two cubes are then brought into contact until thermal equilibrium is achieved.

Assuming that no thermal energy is transferred from the cubes to the surroundings, what is the final temperature of both cubes?

A 31 °C **B** 38 °C **C** 42 °C **D** 50 °C

17 An ideal gas is contained in a cylinder by a piston as shown. The volume of the gas is decreased by moving the piston rapidly in the direction shown.



The average speed of the gas molecules increased initially.

Which statement explains this?

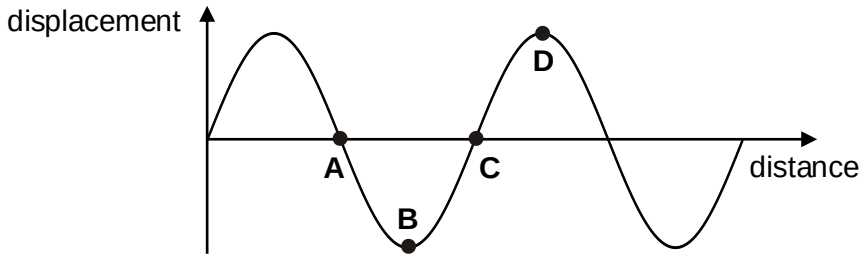
A The molecules have a smaller volume to move about.

B The molecules make more collisions with each other per unit time.

C The molecules make more collisions with the cylinder walls and piston per unit time.

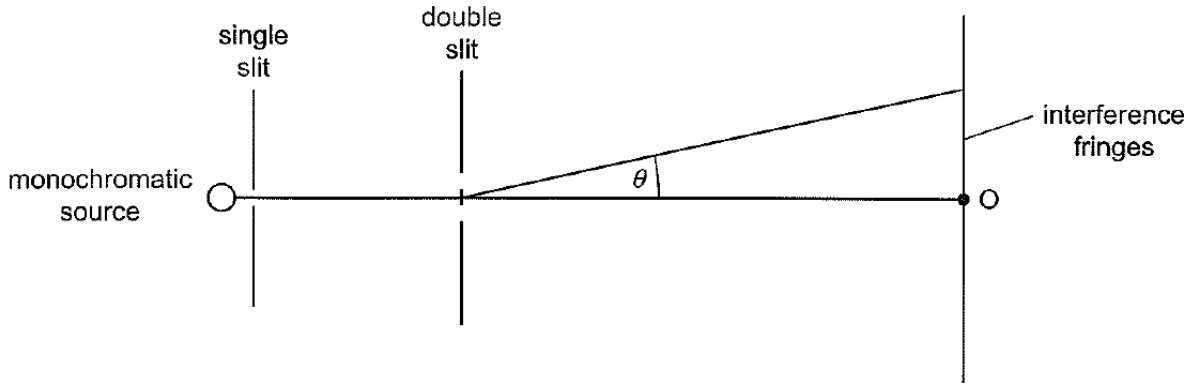
D The molecules gain energy from the moving piston as they collide with it.

18 A sound wave travelling towards the right through air causes the air molecules to be displaced from their equilibrium positions. The graph below shows the variation with distance of the displacement of air molecules at a particular instant of time.

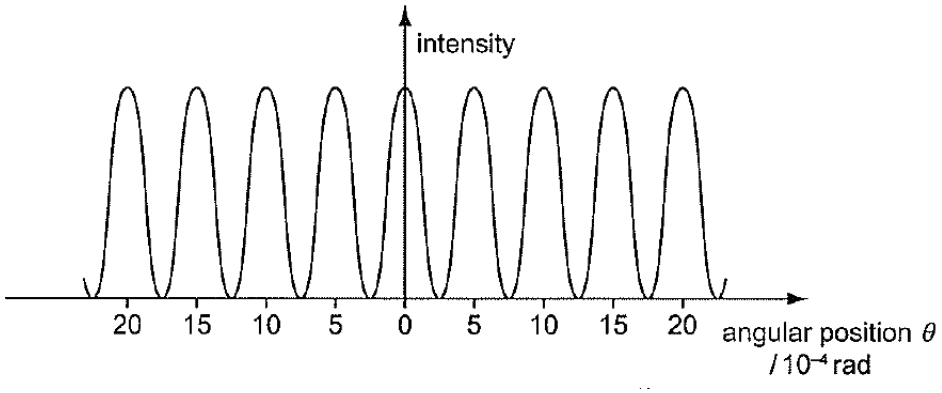


Taking the displacement towards the right as positive, which is a point of rarefaction?

19 A double slit is illuminated by monochromatic light of wavelength 7.0×10^{-7} m and interference fringes are observed.



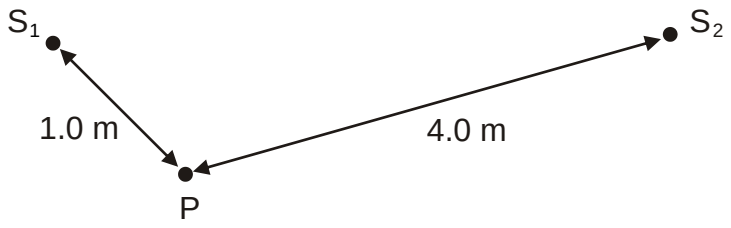
The intensity of the fringes varies with angular position θ as shown.



What is the separation of the double slit?

A 0.5 mm **B** 0.7 mm **C** 1.4 mm **D** 2.8 mm

20 Water waves of wavelength 2.0 m are produced by two sources S_1 and S_2. The sources vibrate in anti-phase.



Point P is 1.0 m from S_1 and 4.0 m from S_2. S_1 alone and S_2 alone each produces a wave of amplitude A and $2A$ at P respectively. Which one of the following is the amplitude of the resultant wave at point P when S_1 and S_2 are both emitting waves?

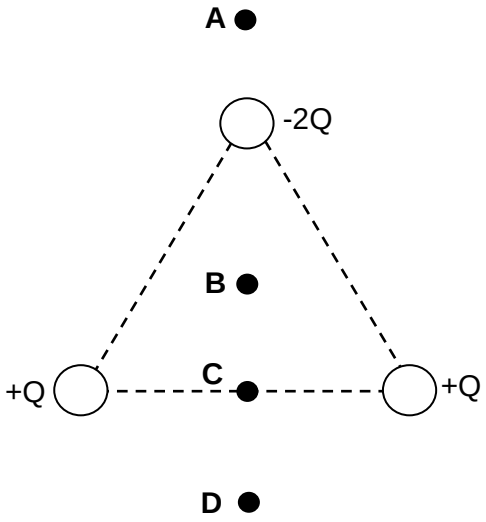
A zero **B** A **C** $3A$ **D** $9A$

21 A diffraction grating gives a green light of wavelength 5.40 x 10^{-7} m in a certain order superimposed on the violet line of wavelength 4.05 x 10^{-7} m of the next order.

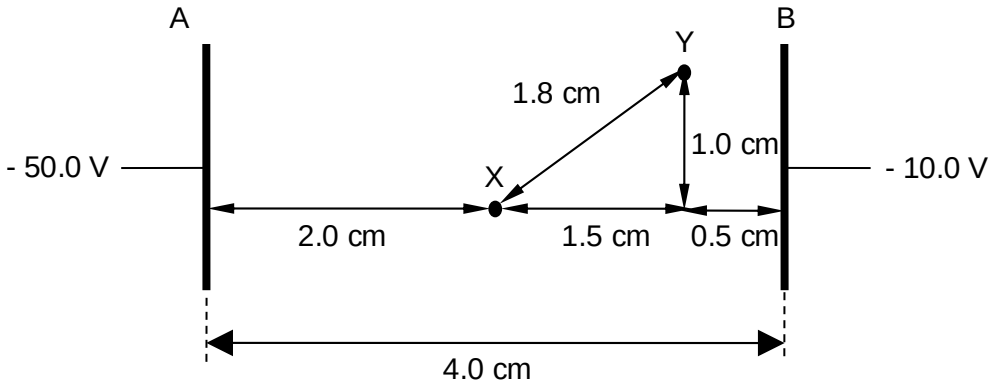
If the angle of diffraction is 30^0, what is the number of lines per metre in the grating?

A 1.80 x 10^5 **B** 3.09 x 10^5 **C** 4.26 x 10^5 **D** 1.35 x 10^6

22 Three charges of charge +Q, +Q, and -2Q rest at the corners of an equilateral triangle as shown. A small test charge +q is brought near the three charges. At which of the following positions would it be possible for the small test charge to experience a zero net force?



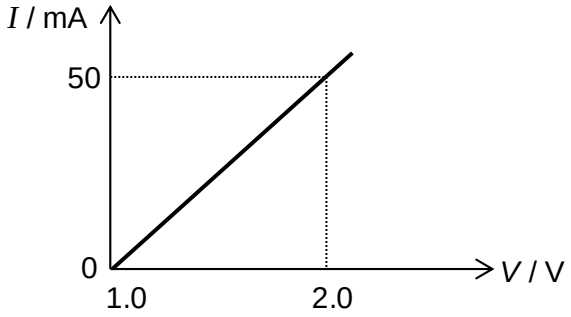
23 Two parallel conducting plates A and B are 4.0 cm apart.



What is the potential difference between points X and Y?

A 15 V **B** 20 V **C** 25 V **D** 40 V

24 The graph below shows the relation between the direct current I in a certain conductor and the potential difference V across it. When V is less than 1.0 V, the current is negligible.



Which statement about the conductor is correct?

A It does not obey Ohm's law but when V = 1.5 V, resistance = 20 Ω

B It does not obey Ohm's law but when V = 1.5 V, resistance = 60 Ω

C It obeys Ohm's law and when V = 1.5 V, resistance = 20 Ω

D It obeys Ohm's law and when V = 1.5 V, resistance = 60 Ω

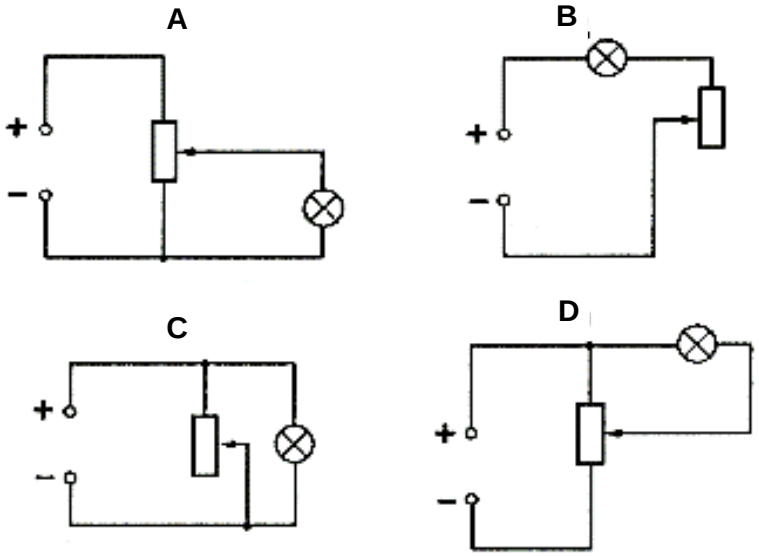
25 The potential difference between point X and point Y is 20 V. The time taken for charge carriers to move from X to Y is 15 s and in this time the energy of the charge carriers changes by 12 J.

What is the current between X and Y?

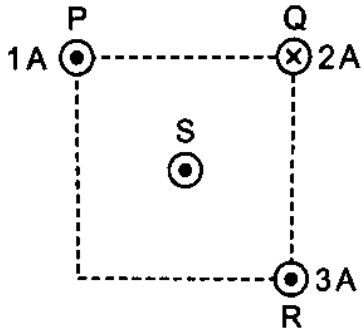
A 0.040 A **B** 0.11 A **C** 9.0 A **D** 25 A

26 A lamp is connected to a power supply of negligible resistance.

Which circuit could **not** be used as a practical means to vary the voltage across the lamp?



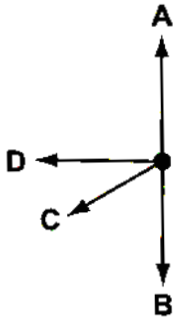
27 The diagram below shows a horizontal plane through which four long straight vertical wires pass.



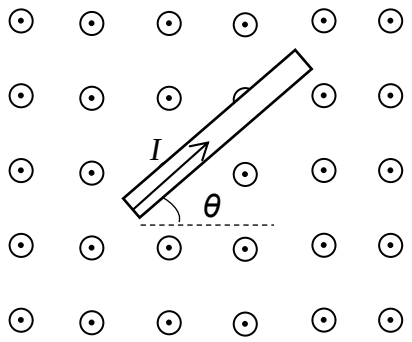
Wires P, Q and R are at three corners of a square and wire S is at the centre.

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.

Which one of the arrows below shows the direction of the force on wire S?



28 A wire of length 3.5 cm is placed on a vertical plane in a region of magnetic field. Uniform magnetic field of flux density 0.080 T is directed out of the plane as shown. The wire makes an angle θ with the horizontal and carries a current I of 4.0 A in the direction as shown.



Which of the following is true about the magnitude of the force which the field exerts on the wire at different angles of θ from 0° to 360°? (Assume that the rod remains in the magnetic field throughout)

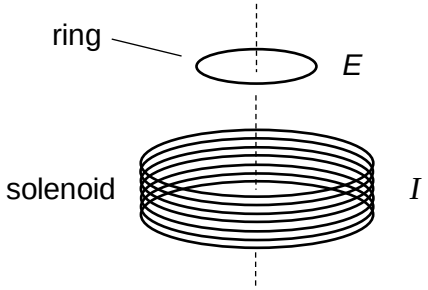
A The force is constant at 0 N.

B The force varies between 0 N and 0.0112 N.

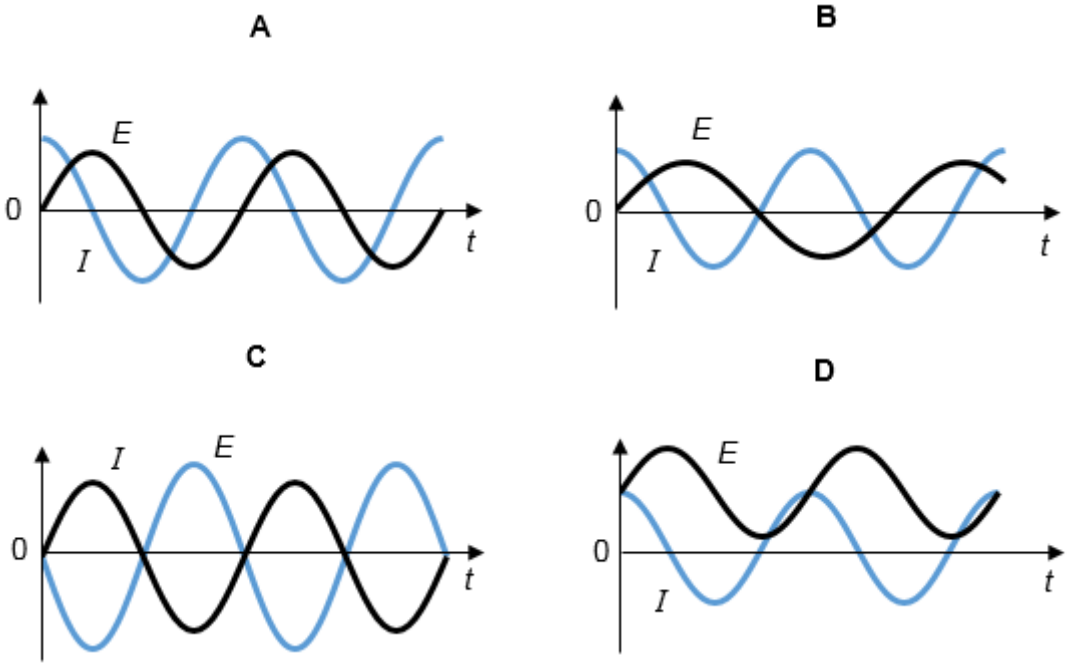
C The force is constant at 0.0112 N.

D The force varies between 0.0112 N and 0.0224 N.

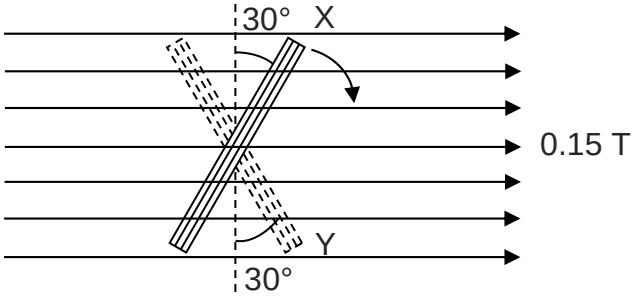
29 A ring is levitated in mid-air due to the e.m.f. E induced in it by the fluctuating magnetic field generated by a sinusoidal current I in the solenoid directly under it.



Which of the following graphs shows the phase relationship between I and E ? Assume that the magnetic flux density at the ring's position due to the solenoid is proportional to the current in the solenoid.



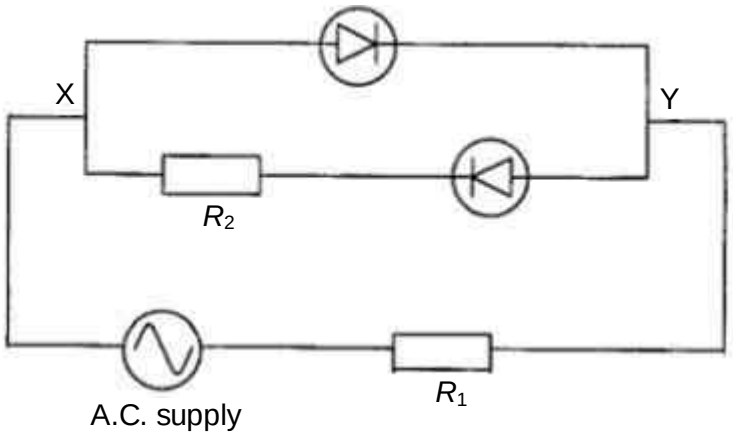
30 A coil of 10 turns and area 1.2 m^2 is rotated in a uniform magnetic field of flux density 0.15 T from position X to position Y in 2.0 s.



What is the average e.m.f. induced in the coil during the rotation?

A 0 V **B** 0.90 V **C** 1.6 V **D** 1.8 V

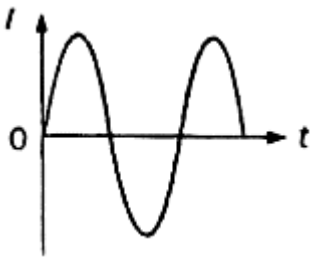
31



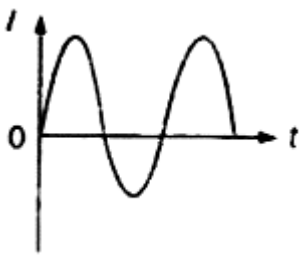
A circuit consists of an A.C. supply, two diodes, and two resistors with resistance R_1 and R_2 respectively.

Which of the following graphs below represents the variation of current I with time t through XY of the circuit in the diagram above?

A



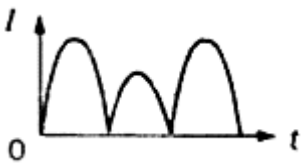
B



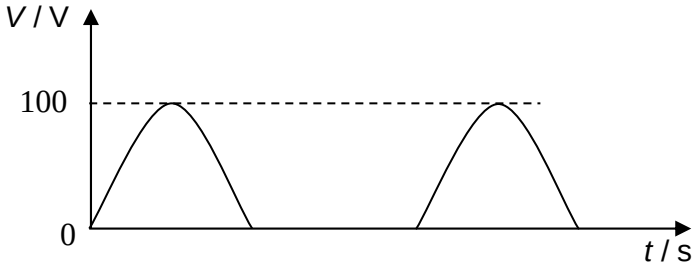
C



D



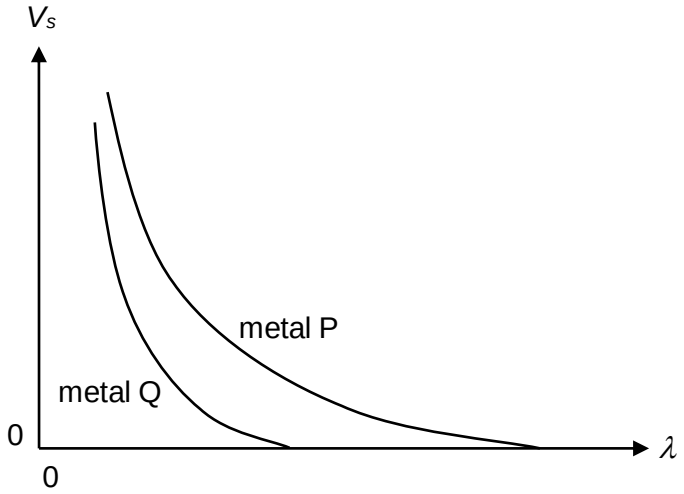
32 Half-wave rectification of an alternating sinusoidal voltage of amplitude 100 V gives the waveform shown in the figure below.



The r.m.s. value of the rectified voltage is

A 25.0 V **B** 50.0 V **C** 70.7 V **D** 100 V

33 The figure below shows the variation of stopping potential V_s with the wavelength of the radiation λ incident on 2 different metals, P & Q.



Which of the following statements is correct?

A The gradient of the tangent to the curve gives the value of the Planck constant.

B The work function of metal P is higher than Q.

C The intensity of light incident on metal P is higher than that on Q.

D Light of higher frequency is required to produce photoelectric effect in metal Q than in P.

34 A laser emits light of power P. The light consists of photons of frequency f. The Planck constant is h and the speed of light is c.

How many of these photons are contained in a one metre length of the laser beam?

A $\frac{P}{c}$ **B** $\frac{P}{hf}$ **C** $\frac{Pc}{hf}$ **D** $\frac{P}{chf}$

35 Which of the following best describes why a barrier of fixed width might be considered wide for penetration by protons, yet at the same time narrow for penetration by electrons?

A The mass for a proton is higher than the mass of an electron, hence probability of penetration by protons is lesser.

B The size of a proton is larger than the size of an electron, hence probability of penetration by protons is lesser.

C The speed of a proton is slower than the speed of an electron, hence the barrier appears relatively wider for the protons.

D The de Broglie wavelength of the proton is smaller than that of an electron, hence the barrier is considered to be wider for protons.

36 A semiconductor can be doped with a small amount of arsenic, a Group V element. Which of the following statements about this semiconductor is **incorrect**?

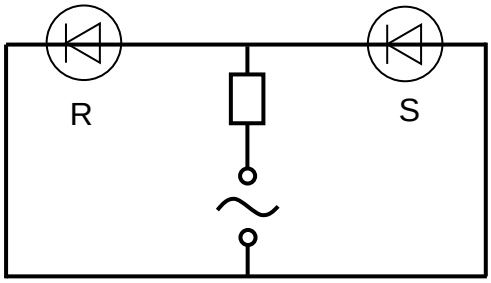
A Its conductivity increases with increasing temperature.

B Its resistivity increases with decreasing amount of arsenic added.

C When an electron is excited from the donor level to the conduction band, it leaves behind a positively charged arsenic atom.

D When an electron is excited from the valence band to the acceptor level, it leaves behind a hole in the valence band.

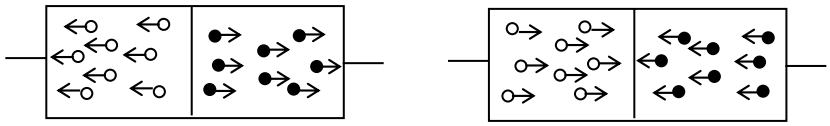
37 Two diodes, R and S, are connected to an alternating source as shown below.



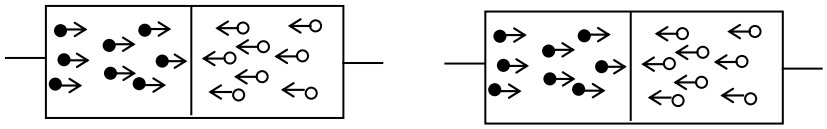
Which of the following shows a possible movement of majority charges in the two diodes at a particular instance in time?

Legend: ● electron ○ hole

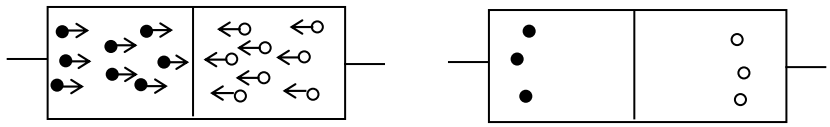
A



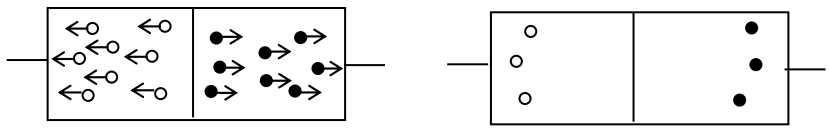
B



C



D



38 What is the approximate mass of a Uranium-235 nucleus?

A 10^{-15} kg **B** 10^{-20} kg **C** 10^{-25} kg **D** 10^{-30} kg

39 When Rutherford fired α-particles at thin gold foil the results of his experiment helped us to understand more about the structure of the atom.

Which conclusion was drawn from the results?

A The nucleus contains protons and neutrons.

B The atom contains a small positively charged nucleus.

C The atom contains the same number of electrons and protons.

D Neutrons and protons are significantly more massive than electrons.

40 One possible reaction of uranium is shown by the equation

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{98}_{40}Zr + ^{135}_{52}Te + 3^{1}_{0}n$$

The binding energy per nucleon *E* of some nuclides are given below.

nuclide	*E* / MeV
$^{235}_{92}U$	7.6
$^{98}_{40}Zr$	8.6
$^{135}_{52}Te$	8.4

How much energy is released in this reaction?

A 8.2 MeV **B** 9.4 MeV **C** 190 MeV **D** 210 MeV

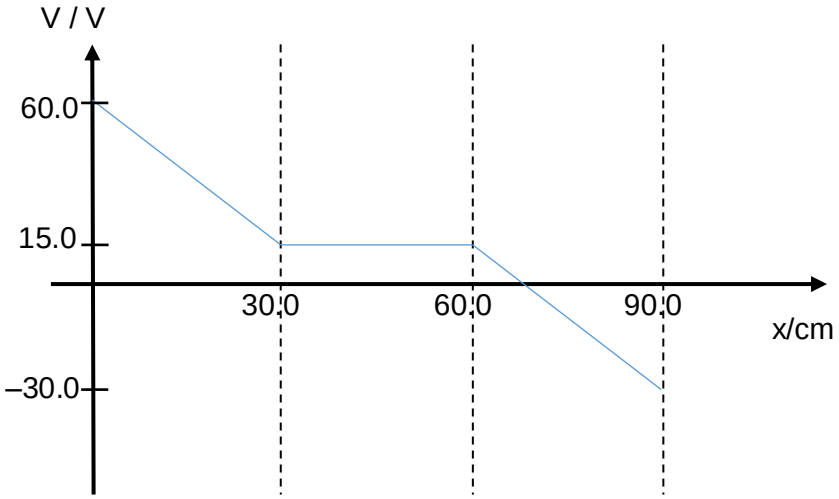
2016 AJC H2 Phy Prelim Solutions

Section A

1a

The electric field of force is a region of space where a stationary charge experiences a force.
The direction of the electric field is the direction of the force on a positive charge.

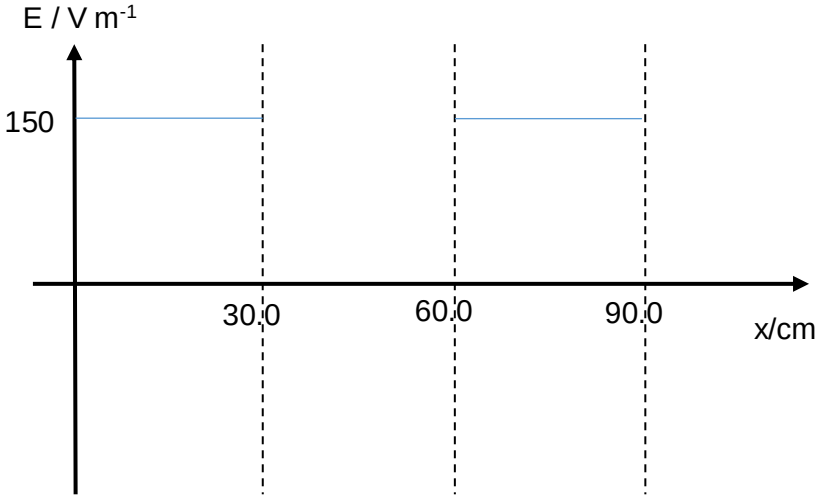
bi



Correct shape:-
Straight lines with negative gradient (AP & QB)
Zero gradient (PQ)
Equal gradient - AP and QB.

Correct labels:-
Potential at P and Q is 15.0 V and V_A = 60 V, V_B = –30 V
Accept labelling of x axis (A,P,Q,B)

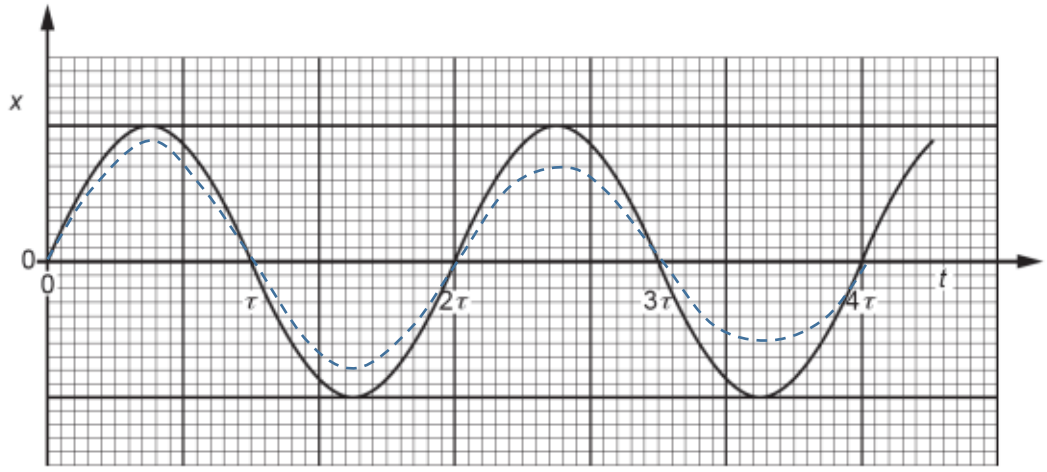
bii



$E = -\frac{dV}{dx} = -\frac{15.0 - 60.0}{0.300} = 150 \text{ V m}^{-1}$.
E between AP and QB is 150 V m^{-1}
E between PQ is zero.

c	Region AP: When the thickness is increased, the distances AP and QB decrease while p.d. across AP and QP remained the same. Since E = -dV/dx OR due to larger p.d. drop per unit distance, the electric field strength will increase between AP. Region PQ: The potential at P and Q will remain the constant. Hence the electric field strength between P and Q will remain at zero.
di	(Since the electric force is the only force acting on the beta particle, it will undergo projectile motion) and travel a parabolic path towards plate A.
dii	Magnitude of electric force $= q\frac{V}{d}$ $= 1.6 \times 10^{-19} \times \frac{90.0}{90.0 \times 10^{-2}}$ $= 1.6 \times 10^{-17}$ N Acceleration of the beta particle = F / m $= 1.6 \times 10^{-17} / 9.11 \times 10^{-31}$ $= 1.756 \times 10^{13}$ m s^{-2} vertically, $y = ut$ $0.200 = ut$ $t = \frac{0.200}{u}$ --- (1) horizontally, $x = 0 + \frac{1}{2} at^2$ $0.450 = \frac{1}{2} (1.756 \times 10^{13}) t^2$ --- (2) Sub (1) into (2), $0.450 = \frac{1.756 \times 10^{13}}{2} (\frac{0.200}{u})^2$ $u = 8.834 \times 10^5 = 8.83 \times 10^5$ m s^{-1} accept 8.84×10^5 m s^{-1}

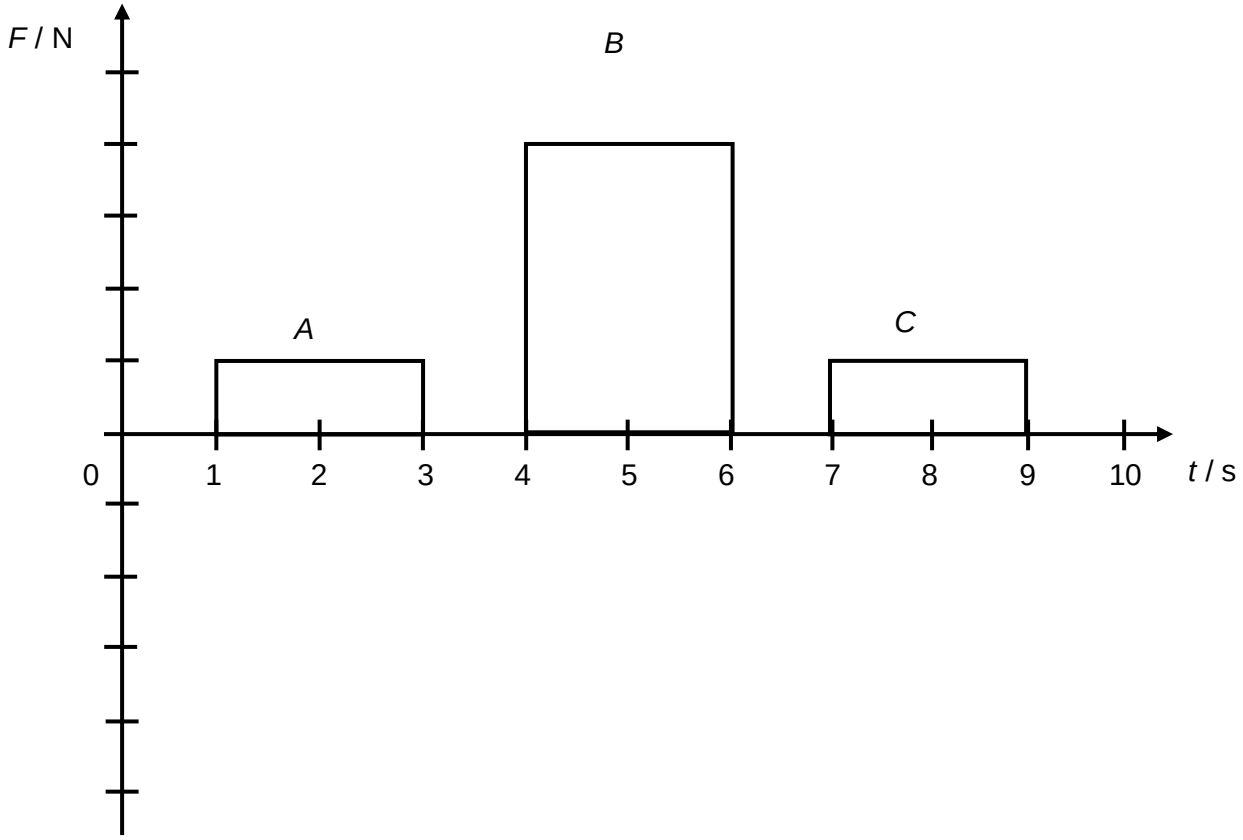
2a	(magnitude of) acceleration is constant so cannot be s.h.m.
2b(i)	g and r are constant so a is proportional to x negative sign shows a and x are in opposite directions

2b(ii)	$\omega^2 = \frac{g}{r}$ and $\omega = \frac{2\pi}{T}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{9.81}{0.28}$ $T = 1.06s$ time interval = T/2 = 0.53 s
2c	sketch: time period constant (or increases very slightly) drawn line always 'inside' given loops successive decrease in peak height 
3a	An ideal gas is one which obeys the equation of state pV = nRT at all pressures, volumes and temperatures.
3b	Using pV = nRT, $(3.4 \times 10^5) \times (2.5 \times 10^3) \times 10^{-6} = n_A \times 8.31 \times (273.15 + 27)$ $n_A = 0.34078$ mol. Considering the gas in cylinders A and B as a system, $p_{AB}V_{AB} = n_{AB}RT'$, where T' is the final temperature of the gas. $(4.0 \times 10^5) \times [(2.5 + 1.6) \times 10^3] \times 10^{-6} = (0.34078 + 0.20) \times 8.31 \times T'$ T' = 364.941 = 365 K
3c	Since there is no thermal energy entering or leaving the system and there is no work done on the gas (no change in volume of the gas), the internal energy of the gas remains constant with the opening of the tap.

4 (a) (i)	The frame experiences an increase in flux linkage. By Faraday's law, an emf is induced across XY. By Lenz's Law, a current is induced in the frame and flows clockwise (X → Y→ Z → W), resulting in a magnetic force on XY to the left / against its motion.

	To maintain constant speed, there should be no net force. Hence, an external force needs to be applied to the right. **OR** The frame experiences an increase in flux linkage. By Faraday's law, an emf is induced across XY. A current is induced in the frame, resulting in kinetic energy of the frame to be transformed to thermal energy if no external force is applied. To maintain constant speed, work has to be done by an external force so that the kinetic energy is maintained.
(ii)	Induced emf = BLv = (1.0)(0.020)(0.010) = 2.0×10^{-4} V $F = BIL$ $= (1.0)[\frac{(2.0\times10^{-4})}{8.0\times10^{-4}}](0.020)$ = 5.0×10^{-3} N **OR** Induced emf = BLv = (1.0)(0.020)(0.010) = 2.0×10^{-4} V Heat dissipated in one second = $\frac{V^2}{R}$ $= \frac{(2.0\times10^{-4})^2}{8.0\times10^{-4}}$ = 5.0×10^{-5} J $F = \frac{P}{v} = \frac{5.0\times10^{-5}}{1.0\times10^{-2}}$ = 5.0×10^{-3} N

(b)



B1 – Correct shape for *B* (magnitude of *F* around 4.0 times higher than *A*)
B1 – Correct shape for *C* (magnitude of *F* same as *A*)
Examiner's comments:

Note:
From t = 1 s to t = 3 s, only one side of the coil (XY) experiences a force to the left as the induced current in XY is perpendicular to the magnetic field.

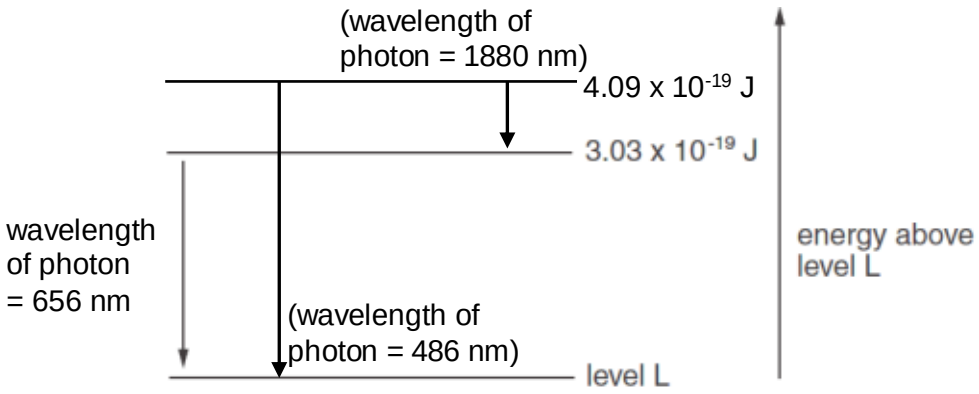
From t = 3 s to t = 4 s, the entire frame is inside region A. The frame experience no change in magnetic flux linkage, so no emf is induced.

From t = 4 s to t = 6 s, there is induced emf of equal magnitude but opposite polarity at both WZ and XY. Hence the magnitude of induced emf doubles to 4.0×10^{-4} V. Both WZ and XY experience a force of twice the magnitude to the left. Therefore the magnitude of *F* increases by 4 times (2.0×10^{-2} N).

From t = 6 s to t = 7 s, the entire frame is inside region B. The frame experience no change in magnetic flux linkage, so no emf is induced.

From t = 7 s to t = 9 s, only one side of the coil (WZ) experiences a force to the left as the induced current in XY is perpendicular to the magnetic field. The magnitude of emf induced = $\frac{\Delta\Phi}{t} = \frac{B\Delta A}{t} = \frac{Bl\Delta s}{t} = Blv$, which is the same magnitude of emf induced from t = 1 s to t = 3 s, since v and magnitude of *B* is the same.

5a	Specific (coloured) line shows that only photons of discrete/specific wavelength / frequency are emitted.

	Since photon energy = Planck constant × frequency is equal to the energy difference between two energy levels, Hence, energy levels are discrete.
5bi	$E = hc/\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (486 \times 10^{-9})$ $= 4.09 \times 10^{-19}$ J
5bii	 energy drawn and labelled at 4.09×10^{-19} J higher than 3.03×10^{-19} J. Transition from 4.09×10^{-19} J to level L clearly shown, corresponding to 486 nm. Transition from 4.09×10^{-19} J to 3.03×10^{-19} J clearly shown, corresponding to 1880 nm.
5ci	Stimulated emission occurs when an <u>incident photon</u> causes an <u>excited electron</u> to make a <u>downward transition</u> <u>emitting a photon</u> identical to the incident photon. The emitted photon have the <u>same energy, phase, frequency, polarisation, and direction of travel</u> as the incident photon.
5cii	The incoming photon from the flash lamp has an energy that matches the energy difference of E_2 and E_0. Since $E_2 \rightarrow E_0$ is a possible energy transition, <u>the incoming photon could stimulate a de-excitation from E_2 to E_0</u>, if the lifetime at E_2 is long. As a result, <u>population inversion at E_1 cannot be achieved</u> and the required lasing wavelength due to $E_1 \rightarrow E_0$ transition cannot occur.
5ciii	$E_2 - E_1 = 2.25 - 1.79 = 0.46$ eV $= 0.46 \times 1.6 \times 10^{-19} = 7.36 \times 10^{-20}$ J $E = hf \rightarrow f = E / h = 7.36 \times 10^{-20} / (6.63 \times 10^{-34})$ $= 1.11 \times 10^{14}$ Hz

6a		power *P* / kW	total mass *m* / kg	(*P*/*m*) / kW kg^{-1}	
		0.65	200	0.00325	

0.95	250	0.00380
1.90	300	0.00633
3.15	350	0.00900

If P is proportional to m, then P/m will give a constant. However, from the table above, the values of P/m does not give a constant, and hence the student's proposal is incorrect.

2m – table with 3 or 4 sets of data of P, m and P/m with some reasoning
1m – table with only 2 sets of data of P, m and P/m with some reasoning
0m – table with only 1 set of data or less of P, m and P/m with some reasoning OR reasoning only

Note: Candidates should be advised that where the question involves an instruction to 'show' then full working is expected. **The candidates who only gave a descriptive answer were not considered to have answered the question**.

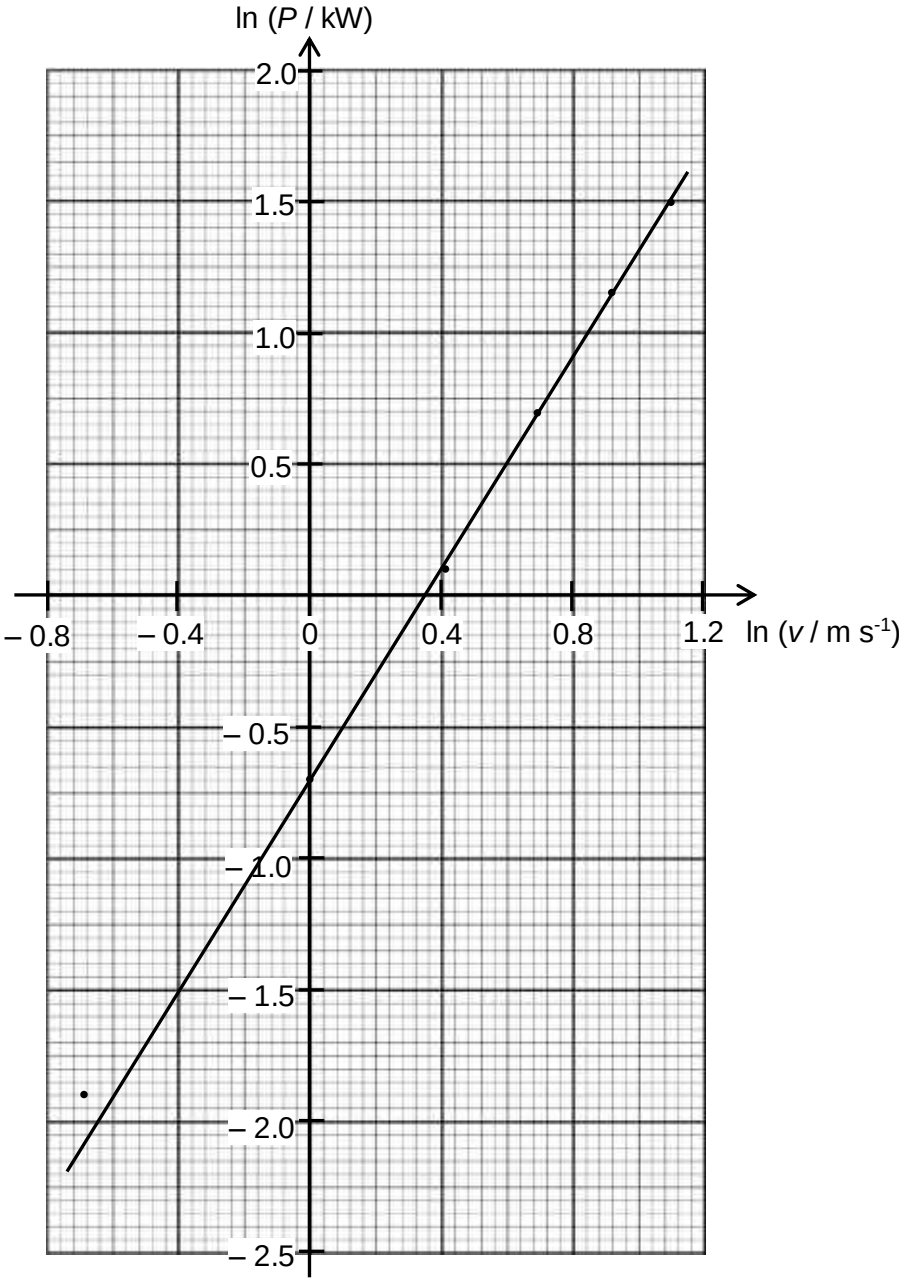
6bi

speed v / m s^{-1}	ln (P / kW)	ln (v / m s^{-1})
0.5	**– 2.30 to – 1.90**	**– 0.69**
1.0	– 0.69	0.00
1.5	0.10	0.41
2.0	0.69	0.69
2.5	1.15	0.92
3.0	1.50	1.10

read off to the nearest half small square for P (accept reading either 0.10 / 0.15 resulting in ln (P/kW) of -2.30 / -1.90)

6bii & 6biv

ii. Points plotted correctly to half the small square (according to student's result)



iv. Best-fit line drawn either as above or with a balance of points on either side of line.

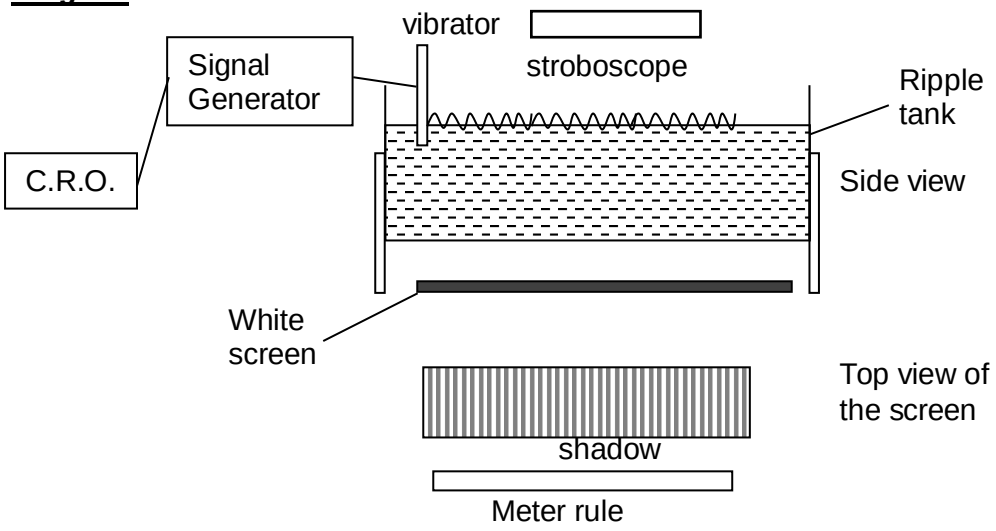
6biii	$P = kv^n$ ➔ ln (P) = ln k + n ln (v) By plotting a graph of ln (P) against ln (v), we should be get a straight line graph with gradient of n and y-intercept ln k. Since the points on Fig 6.3 follows a linear trend, it supports the proposed equation $P = kv^n$.
6biv	Drawing of best-fit line on Fig. 6.3 (see graph above) Using the coordinates (1.12, 1.55) and (-0.72, -2.15) Gradient of line = (1.60 + 2.05) / (1.16 + 0.68) = 2.0109 Hence, n = 2 (no decimal figures)
6c	With a total mass of 300 kg and travelling at a steady speed of 2.5 m s^{-1}, P = 1.9 kW (from Fig. 6.1). Hence, using P = Fv, the forward driving force = P / v = 1900 / 2.5 = 760 N Since the boat is travelling at steady speed, by Newton's 2nd Law, there is no resultant force on the boat. The magnitude of the forward driving force must be equal to the drag force. Therefore, drag force = 760 N
6d	Total power supplied to the outboard motor = rate of fuel consumption x energy density fuel = (1.1 / 3600) x 32 x 10^6 = 9777.778 W efficiency = Useful power output / Total power supplied = 1900 / 9777.778 = 0.19431 = 0.19 Accept 19 %.

Q7. Solution to Planning Question

Version 1

Independent variable	Dependent variables	Control variables
What? Depth of water *d*	Speed of wave *v*	• temperature of water • prevent draughts
How? Half metre rule Remove some water	$v = f\lambda$ *f* from CRO λ from metre rule with stroboscope	• use same water • enclose room

Diagram



Define Problem

To investigate how the speed of water waves *v* varies with the depth of the water *d* keeping temperature of water constant, to determine the value of *n*.

Procedure

1. Set up the apparatus as shown above.
2. Fill the ripple tank with water to a depth *d* as measured with a half meter rule. Record *d*.
3. Produce a train of transverse waves on the surface of water using a vibrator which is run by a signal generator. Frequency *f* of the signal generator is found with the CRO. Record *f*.
4. A stroboscope is placed above the ripple tank to cast shadows of the wavefronts on the white screen placed under the transparent tank. The frequency of the stroboscope is adjusted to freeze the wave pattern on the screen.
5. Place a metre rule on the screen to measure the wavelength λ, distance between two consecutive crests (bright lines) or trough (dark lines).
6. Calculate velocity of wave using $v = f\lambda$.
7. Repeat the experiment to obtain 6 sets of data of *v* and *d*, by removing some water each time to reduce *d*.

Control of Variables

1. Keep the temperature of water constant by conducting the experiment at room temperature and use the same water throughout the experiment where water is removed from the ripple tank in the variation of depth *d*, instead of adding water which may change the temperature.
2. Conduct the experiment in an enclosed room to prevent draughts from affecting speed of the waves.

Analysis

1. From $v = k\,d^{\,n}$, $\lg v = n \lg d + \lg k$
2. Plot a graph of $\lg v$ against $\lg d$ and find *n* by calculating the gradient of the graph.

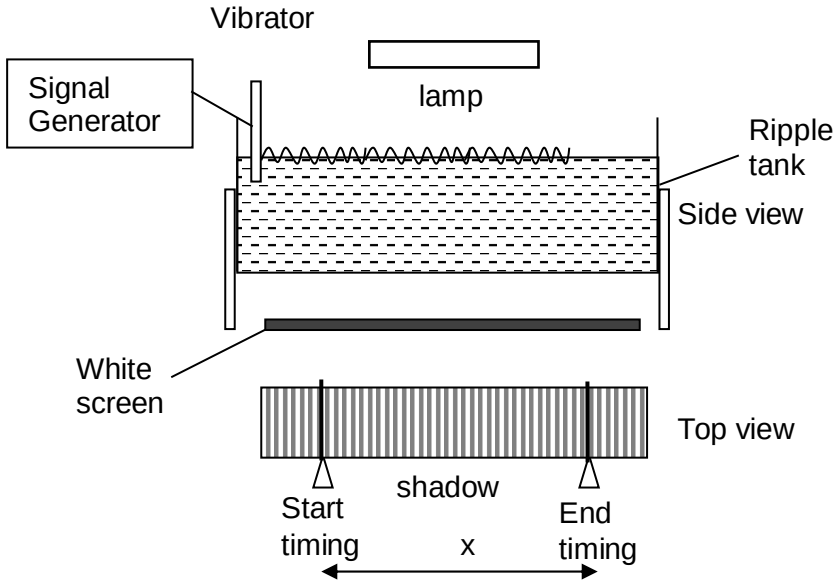
Accuracy and Safety

1. Ensure that the ripple tank is horizontal using a spirit level so as to keep the depth of the water uniform.
2. For each *d*, repeat the experiment with a different frequency of the signal generator to find average velocity.
3. For each *d*, measure distance $N\lambda$, find the average wavelength λ by calculating $N\lambda/N$
4. Ensure hands are dry before handling the electrical appliance to prevent electric shocks.

Version 2

Independent variable	Dependent variables	Control variables
What? Depth of water *d*	Speed of wave *v*	• temperature of water • prevent draughts
How? Half metre rule Remove some water	Metre rule, stopwatch	• use same water • enclose room

Diagram



Define Problem

To investigate how the speed of water waves v varies with the depth of the water d keeping temperature of water constant, to determine the value of n.

Procedure

1. Set up the apparatus as shown above.
2. Fill the ripple tank with water to a depth d as measured with a half meter rule. Record d.
3. Produce a train of transverse waves on the surface of water using a vibrator which is run by a signal generator.
4. A lamp is placed above the ripple tank to cast shadows of the wavefronts on the white screen placed under the tank.
5. Mark 2 lines a distance x apart on the white screen. Measure and record x with a metre rule.
6. Measure and record the time taken t for a shadow of trough to travel distance x with a stopwatch.
7. Calculate speed with $v = x / t$
8. Repeat steps 2 to 6 to obtain 6 sets of data of v and d by removing some water each time to decrease the water depth d.

Control of Variables

1. Keep the temperature of water constant by conducting the experiment at room temperature and use the same water throughout the experiment where water is removed from the ripple tank in the variation of depth d, instead of adding water which may change the temperature.
2. Conduct the experiment in an enclosed room to prevent draughts from affecting speed of the waves.

Analysis

1. From $v = k d^{n}$, $\lg v = n \lg d + \lg k$
2. Plot a graph of $\lg v$ against $\lg d$ and find n by calculating the gradient of the graph.

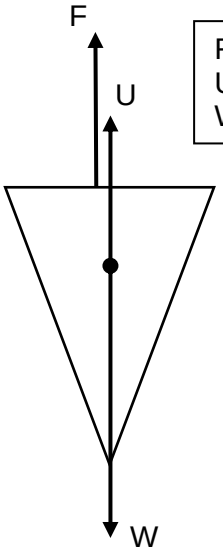
Accuracy and Safety

1. Ensure that the ripple tank is horizontal using a spirit level so as to keep the depth of the water uniform.
2. For each d, repeat the experiment with a different frequency of the signal generator to find average velocity.
3. Ensure that the experimenter does not touch the electrical appliances or power supply with wet hands.
4. Ensure that x is large enough so that percentage uncertainty in t and hence v is reduced.

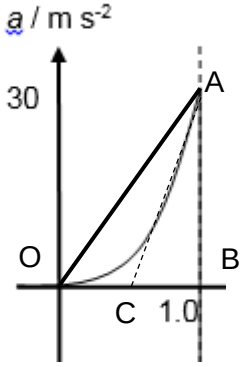
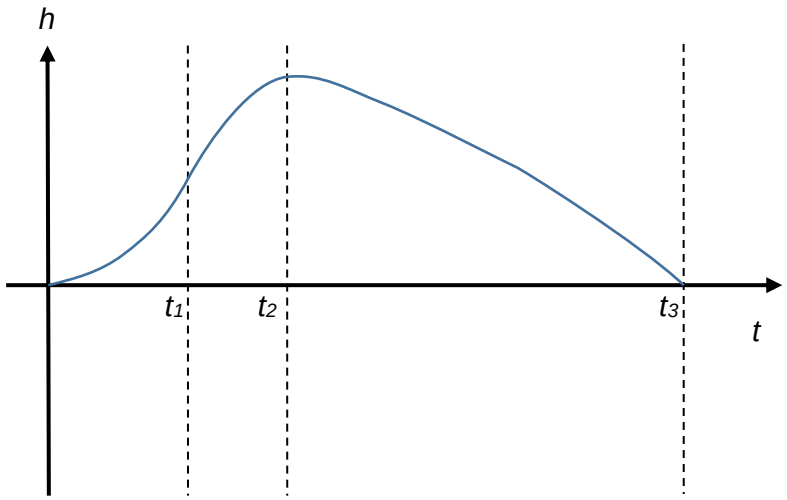
Marking Scheme [12m]

Diagram shows
Workable means to generate waves e.g. vibrator on water surface.
Workable means to visualise the waves e.g. using light source with screen, using stroboscope, using camera, etc.
Basic Procedure
Workable method to measure depth d
Workable method to measure speed based on $v = f\lambda$ or $v = x / t$
Repeat for different depth of water
Correct analysis of data to obtain n
Control of Variables
Control of air flow above the water, i.e., in an enclosed room
Control of temperature / density / viscosity, i.e., using same water throughout
Safety and Accuracy [max: S = 1; S + A = 4]
Dry hands before handling electric equipment to prevent electric shock.
Detail on how to keep the depth of the water uniform (eg ensure that the ripple tank is horizontal by using a spirit level)
Further detail on how to measure frequency of the wave (eg determine frequency from display of CRO)
Use of stroboscope to improve accuracy (reduce random error due to human estimation).
Workable method to take repeated readings to find average velocity for each d
Workable method to measure distance $N\lambda$ and find average wavelength λ for each d.
Place the vibrator in the middle of ripple tank to reduce the effect of reflected waves.
Improve the accuracy of the velocity, use a longer distance travelled.
Ensure that white screen is near to the base of the ripple tank so that shadow distance is less deviated from actual waves.

2016 AJC H2 Phy Prelim Solutions
Paper 3 (80 marks) **E – Easy, A – Average, D – Difficult**

1a	Density of cone $= \frac{m}{\pi r^2 \frac{h}{3}} = \frac{0.170}{\pi(2.50 \times 10^{-2})^2 \frac{0.120}{3}} = 2164.51 \text{ kg m}^{-3}$ $\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} = \frac{0.001}{0.170} + 2\frac{0.0001}{0.0250} + \frac{0.001}{0.120} = 0.0222$ $\Delta\rho = 50 \text{ kg m}^{-3}$ $\rho = (2160 \pm 50) \text{ kg m}^{-3}$
bi	 F: Force by spring U: upthrust W: weight *U and W from the cg of cone (approx. 1/3 from base of cone)* *Length of W equals to sum of lengths of F and U*
bii	$F + U = W$, $F = ke$, $U = \rho_w V_c g$, $W = m_c g$ $50e = 0.170 \times 9.81 - 1000 \times \pi(2.5 \times 10^{-2})^2 \frac{0.120}{3} \times 9.81$ $e = 0.01794 = 0.018$ m

2ai	The rocket exerts a downward force on the gas to eject it out of the rocket. By Newton's third law, the gas exerts an equal and opposite force on the rocket, providing the upward force.
aii	All the gas has been used up and there is no more upward force acting on the rocket. The net force now acts downwards, (or only weight and air resistance act on the rocket) hence the acceleration changes from positive to negative.
aiii	accept value from 7 – 10 N s

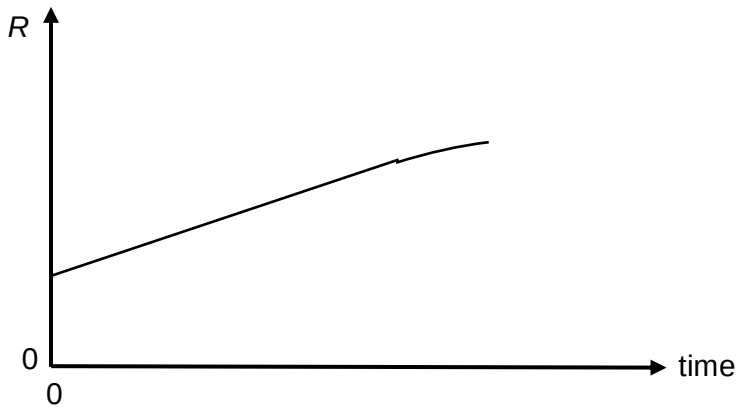
	 Area under triangle OAB is 15 N s. Area OAC is about 7.5 N s. But area under curve OAB is slightly large than that of the triangle OAC.
aiv	Yes. Considering the system of Earth, rocket and gas, there is no external force acting on the system, and there will be no change to their total momentum. Or No. There is a external force acting on the rocket / system of rocket and gas due to the gravitational force of attraction by the earth.
b	

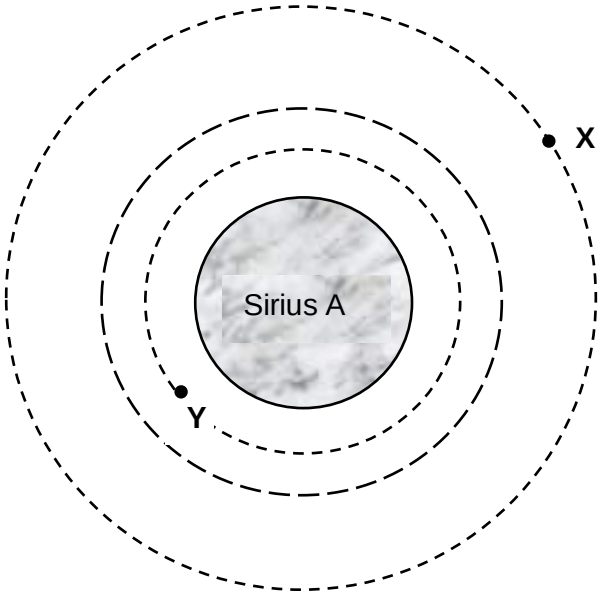
3a	At (displacement) antinodes OR where there are no heaps, wave has maximum amplitude (of vibration). At (displacement) nodes OR where there are heaps, amplitude of vibration is zero/minimum. The dust is pushed to OR settles at (displacement) nodes.
b	2.5 λ = 39 cm, so λ = 15.6 cm v = f λ = 2.14 $\times 10^3 \times 15.6 \times 10^{-2}$ = 334 m s^{-1} (allow 330, not 340)

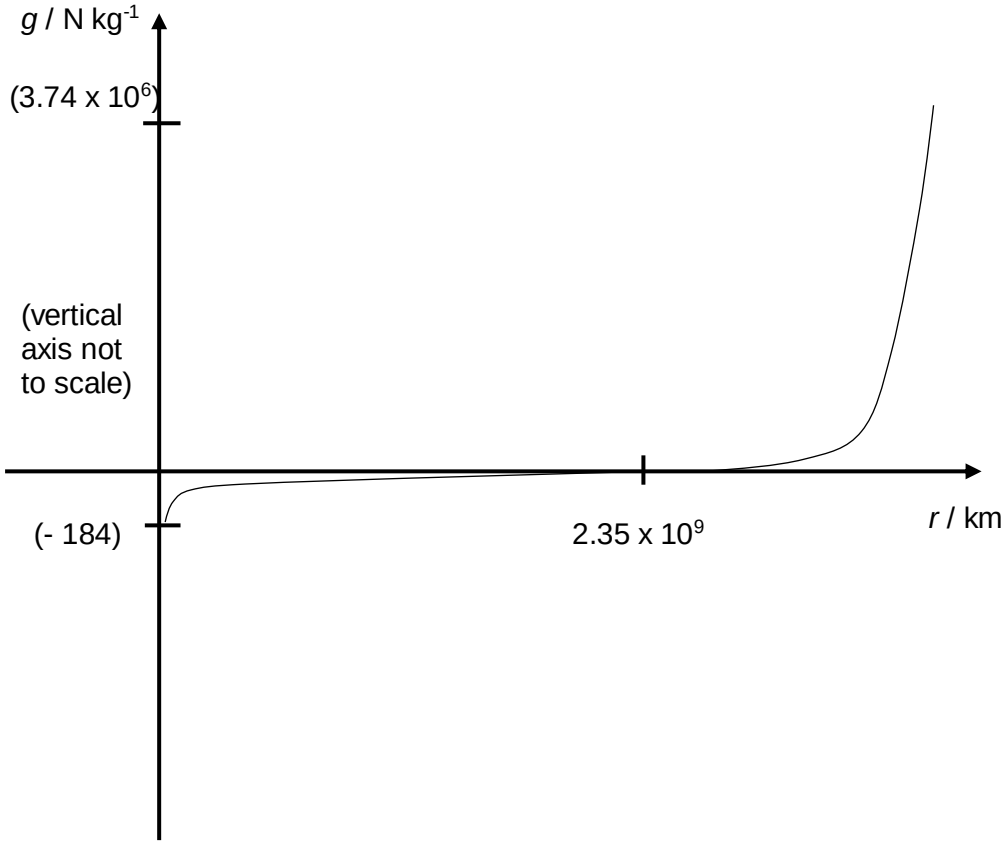
4ai	R = V^2/P R = $120^2/1200$ = 12 Ω
aii	$I_{r.m.s.} = \frac{V_{r.m.s.}}{R}$ =120/12 = 10A $I_0 = \sqrt{2} I_{r.m.s.}$

	$I_0 = 14$ A Since the current is alternating, one should expect either $I = I_0 \sin(\omega t)$ or $I = I_0 \cos(\omega t)$ However, the condition is that the power output is zero at the start where $t = 0$. Hence one should write $I = I_0 \sin(\omega t)$ or $I = -I_0 \sin(\omega t)$ $I = I_0 \sin(2\pi f t)$ $I = -I_0 \sin(2\pi f t)$ $I = 14\sin(100\pi t)$ $I = -14\sin(100\pi t)$ Both positive and negative answers are acceptable but values must be correct.
b	By conservation of energy, Power supplied to primary coil = Power output from secondary coil + power loss. $P_p = P_S + P_{loss}$ $I_P V_P = 1200 + P_{loss}$ $I_P(2400) = 1200 + 600$ $I_P = 0.75$ A
c	The resistance of a wire $R = \rho l/A$ where ρ is its resistivity, l its length and A its cross-sectional area. The length of the wire in the lamp will have to be restricted by the size of the lamp, the so it is about a metre long when uncoiled, while the heating coil has length more than 10 times of that. However, the wire in lamp has resistance of about 30 times that of the heating coil. Both are made of the same material, so they have the same resistivity. Hence, the cross-sectional area of the wire in the lamp may be only a 1/300 that of the heating coil.

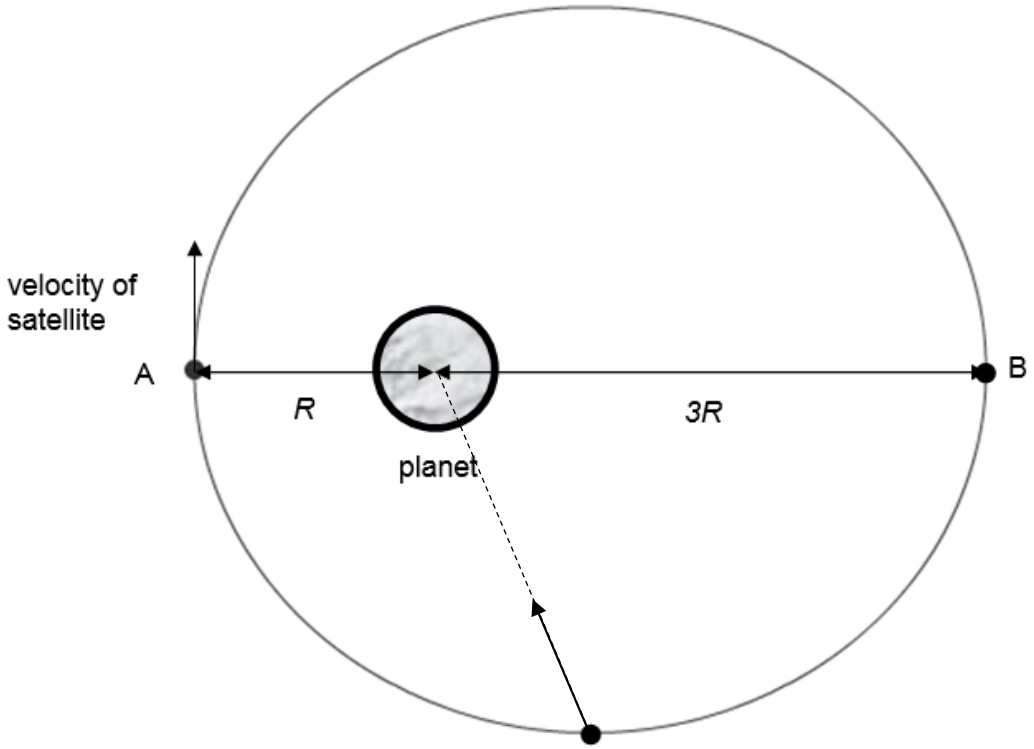
5ai	A <u>neutron</u> in the nucleus <u>decays</u> into a proton and an electron. (Note: ${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e}$)
aii	Half life = ln 2/decay constant = ln 2 / 1.44 x 10^{-11} = 4.8 x 10^{10} year
bi	$\frac{A_{Rb}}{A_0} = e^{-(1.44\text{x}10^{-11})(4.0\text{x}10^{9})}$ $A_{Rb}/A_0 = 0.94$ The activity of Rb <u>has not change much</u> over the age of rock, this showed that its rate of decay remained almost constant.

bii	 Non-zero y-intercept B1 Final gradient slightly less than initial gradient B1
biii	A larger ratio R indicates an older sample. Need to know the initial value of R Need to know the initial ratio of number of Rb to number of Sr-86.

6 (a) (i)	It means that the work done per unit mass in bringing a point mass from infinity to a distance of 2 x 10^6 km from the center of Sirius A is – 1.3 x 10^{11} J kg^{-1}.
(ii)	Gravitational potential is taken to be zero at infinity. Gravitational forces are attractive, hence work done by external agent on the point mass in moving it from infinity is negative.
(iii)	 Equipotential line drawn closer to that of – 2.0 x 10^{11} J kg^{-1}
(iv)	Work done by external agent = $m(\phi_Y - \phi_X)$ = 3000 x [– 2.0 – (– 1.0)] x 10^{11} = – 3.0 x 10^{14} J
(b) (i)	Gravitational force of attraction = centripetal force

	$\frac{GM_AM_B}{r^2} = M_A x_1 \omega^2 = M_B x_2 \omega^2$ $\frac{x_1}{x_2} = \frac{M_B}{M_A} = \frac{1.95}{3.98}$ = 0.49
(ii)	Separation of the stars is much greater than the radii / diameters of the stars.
(iii)	$\frac{GM_A}{r^2} = \frac{GM_B}{(4.0\times10^{12} - r)^2}$ Distance from surface of Sirius A = r – radius of Sirius A = 2.35 x 10^9 km
(iv)	

(c) (i)



Vector directed to centre of planet

(ii)

By COE, $E_{TA} = E_{TB}$

$E_{TA} = KE_A + GPE_A + E_{from\ boost}$

$= (1.5 \times 8.0 \times 10^9) + (-1.6 \times 10^{10})$

$= -4.0 \times 10^9$ J

$E_{TB} = KE_B + GPE_B$

$= KE_B + \frac{1}{3} GPE_A$ (since E_P is inversely proportional to r)

$KE_B = E_{TB} - \frac{1}{3} GPE_A$

$= (-4.0 \times 10^9) - (-1.6 \times 10^{10}) \times \frac{1}{3}$

$= (-4.0 \times 10^9) - (-5.33 \times 10^9)$

$= 1.33 \times 10^9$ J (shown)

(iii)

Gravitational force is insufficient to provide the centripetal force for the satellite to continue in the same circular orbit at the higher velocity.

Gravitational force is not always perpendicular to velocity.

Hence, will not stay in original circular orbit.

OR

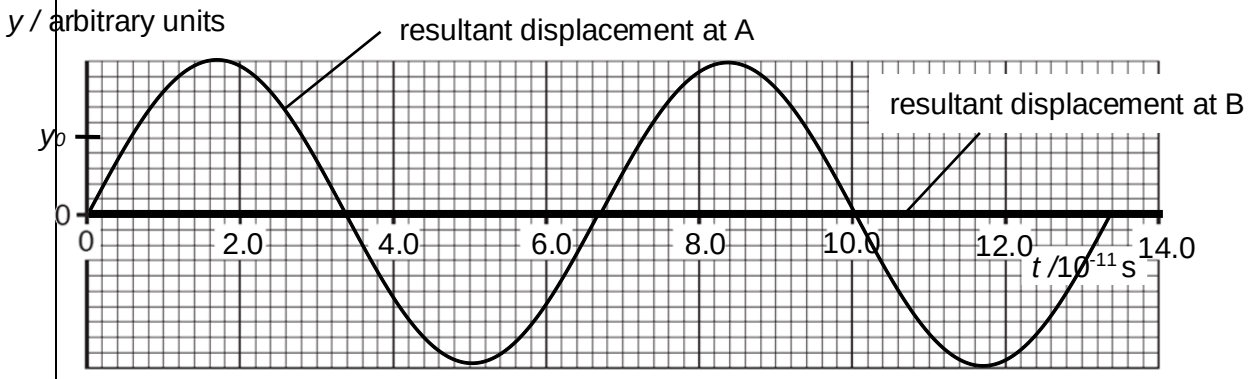
Total energy of satellite increases

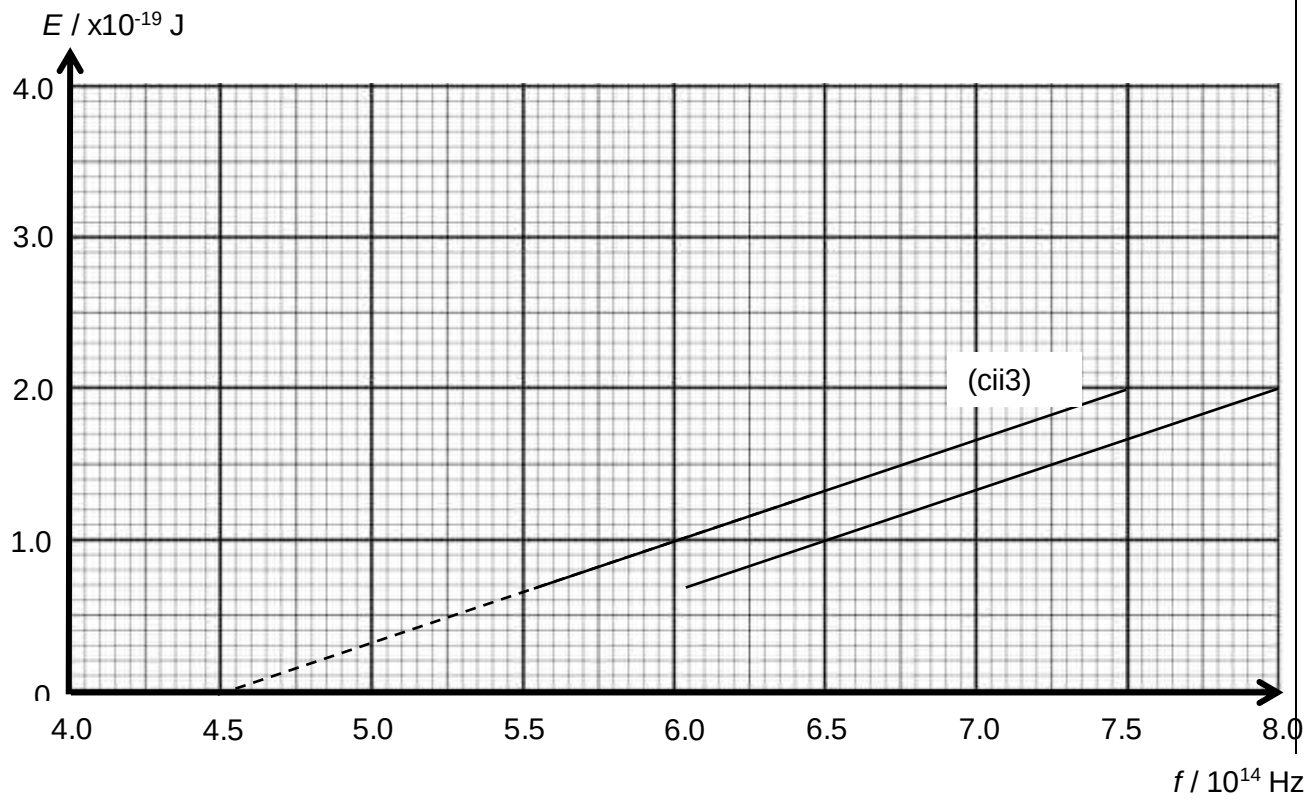
So it has to move to different (greater) distances from Earth

Hence, will not stay in original circular orbit.

7a	Internal energy is the sum of the random kinetic and potential energies of the individual atoms/molecules of the substance
7bi	In a lump of iron that is cooled, the potential energy remains unchanged as the atoms remain in the same position / is reduced because atoms are slightly closer together. The vibrational kinetic energy is reduced because the temperature is lower. Hence the internal energy of the iron decreases.
7bii	When water evaporates, the potential energy increases because the separation of the molecules increases. The kinetic energy of the molecules remains unchanged as the temperature remains unchanged during evaporation. Hence, internal energy of the water increases.
7c	The gas molecules are in random motion and make elastic collisions with the container resulting in a change in momentum of the molecules and hence from Newton's 2nd Law, there is a force acting on the molecules by the wall. From Newton's 3rd Law, this implies that there is an equal and opposite force acting on the wall from the molecules. The pressure is the average force due to the many collisions of the molecules per unit area.
7di	work done by the gas from A to B = $p\Delta V = 10.0 \times 10^5 \times (3.00 - 1.00) \times 10^{-4}$ $= 200$ J
7dii	Since the gas is ideal, potential energy is zero and internal energy is the sum of the random kinetic energies of the molecules. $\Delta U = \frac{3}{2} nR\Delta T$ For the process A→B, since the ideal gas undergoes expansion under constant pressure, $p\Delta V = nR\Delta T$ Hence, $\Delta U = \frac{3}{2} p\Delta V$ $= \frac{3}{2} (200)$ $= 300$ J
7diii	From 1st law of thermodynamics, $\Delta U = Q + W$ Therefore, $300 = Q + (-200)$ $Q = 500$ J
7div	Net work done by gas = area of region enclosed by cycle ABCD = 40 big squares x $(1 \times 10^5 \times 0.5 \times 10^{-4})$ = 200 J Acceptable range: 190 – 210 J Other acceptable estimation can include using trapeziums / triangles to fill the shape.
7dv	Since this is a cyclic process, $\Delta U_{cycle} = 0$. Hence, $Q_{cycle} + WD_{cycle} = 0$ $500 - Q_{C\to D} + (-200) = 0$ where $Q_{C\to D}$ is the thermal energy given out from C to D $Q_{C\to D} = 300$ J (allow ecf for net work done and heat input) Alternatively, For process C→D:

	Since WD = 0, using 1st law of Thermodynamics, $\Delta U = Q$ ⇨ $Q = U_D - U_C$ $= \frac{3}{2} \Delta p\, V = \frac{3}{2} (4.0 - 1.0) \times 10^5 \times 5.0 \times 10^{-4}$ $= 225$ J Note: The difference in the two answers obtained is due to the shape of the adiabetic curves.

8ai	Diffraction occurs at the two slits, which act as coherent sources necessary for formation of interference fringes. At position where path difference is nλ (where n is integer), there is constructive interference and maximum intensity of microwave is detected. At positions where path difference is (n+ ½) λ, there is destructive interference and 0 intensity of microwave is detected.
8aii1	From Fig. 8.2, λ= 2.0 cm. T = 1/f and v = f λ , so T= λ / v $= 0.020 / (3.0 \times 10^8)$ $= 6.7 \times 10^{-11}$ s
8aii2	From Fig. 8.3, at A, path difference = 7.0 – 5.0 = λ, hence constructive interference occurs. at B, path difference = 6.0 – 5.0 = ½ λ, hence destructive interference occurs. 
bi	Concentric circles are evidence of diffraction Diffraction is a wave property
bii	The (de Broglie) wavelength of the electron is much smaller than the slit size for diffraction effects to be observable.
biii	Kinetic energy gained from acceleration through potential difference V, $E_k = qV$. Using $E_k = ½ mv^2$, $p = mv$ and $p = \frac{h}{\lambda}$, we have $p = \sqrt{2qVm} = \frac{h}{\lambda}$ so $\frac{\lambda_\alpha}{\lambda_e} = \frac{p_e}{p_\alpha} = \sqrt{\frac{m_e}{m_\alpha} \times \frac{q_e}{q_\alpha}}$ $= \sqrt{\frac{9.11 \times 10^{-31}}{4 \times 1.66 \times 10^{-27}} \times \frac{1}{2}}$ $= 0.00828$

ci	Particles of electromagnetic radiation can be described as a photon, which is a quantum of electromagnetic energy which is dependent only on the frequency of the radiation.
cii1	Extends line to cut x-axis to obtain the threshold frequency $f_0 = 5.0 \times 10^{14}$ Hz Work function energy = $hf_0 = (6.63 \times 10^{-34})(5.0 \times 10^{14})/1.6 \times 10^{-19}$ = 2.072 = 2.1 eV Allow alternative method on the use of coordinates of points on the line to find y-intercept: $(8.0 \times 10^{14}, 2.0 \times 10^{-19})$ and $(6.5 \times 10^{14}, 1.0 \times 10^{-19})$ $\frac{(2.0-1.0)x10^{-19}}{(8.0-6.5)x10^{14}} = \frac{(2.0-y)x10^{-19}}{(8.0-0)x10^{14}}$ M1 $y = -3.33 \times 10^{-19}$ From equation $hf = \phi + E$, so $E = hf - \phi$ ϕ = – (y-intercept) = 3.33×10^{-19} J = 3.33×10^{-19}/ 1.6×10^{-19} eV = 2.1 eV A1 
cii2	Frequency of photon is below threshold frequency of most metals
cii3	Straight line with the same gradient, displaced to the left with f-intercept between 4.5 to 5.0 x 10^{14} as threshold frequency < 4.5 x 10^{14} Hz, according to information given in **cii2**) (refer to graph in above)

2016 AJC JC2 H2 Physics Prelims Solutions
Paper 1 (40 marks)

1	2	3	4	5	6	7	8	9	10
A	**B**	**C**	**D**	**B**	**C**	**C**	**A**	**B**	**D**
11	12	13	14	15	16	17	18	19	20
D	**D**	**A**	**A**	**A**	**B**	**D**	**C**	**C**	**C**
21	22	23	24	25	26	27	28	29	30
B	**D**	**A**	**B**	**A**	**C**	**B**	**C**	**A**	**C**
31	32	33	34	35	36	37	38	39	40
B	**B**	**D**	**D**	**A**	**D**	**C**	**C**	**B**	**C**

1 **Ans: A**

Min resultant force = 6.0 – 4.0 = 2.0 N
Max resultant force = 6.0 + 4.0 = 10.0 N

2 **Ans: B**

Since the time taken for the ball to reach maximum height is shorter than the time taken for it to fall back to its original height, air resistance is not negligible.

Graph B gives the velocity-time graph for the ball (taking upward as positive) in the presence of air resistance, starting with decreasing upward velocity, followed by zero velocity at maximum height (at t_1) and continuing with increasing downward velocity (negative since upward is taken as positive) beyond t_1.

Note: gradient of *h*-*t* graph is *v*. Hence, variation of slope of *h*-*t* graph should correspond to variation of *v*.

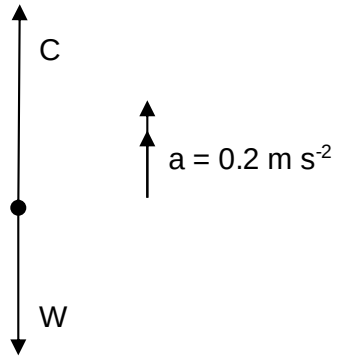
Graph D is wrong as gradient of v-t graph which is acceleration should be decreasing.

3 **Ans: C**

Taking downward as positive
$v = u + gt$
$40 = 0 + 9.81t$
$t = 4.08 = 4.1$ s

4 **Ans: D**

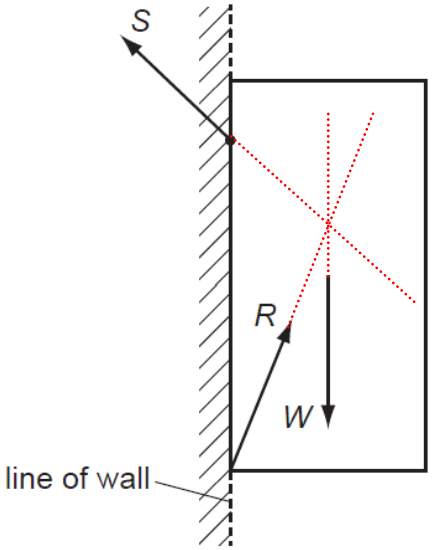
As lift decelerates, the direction of the net acceleration is opposite to the direction of the velocity. Hence, there is a net upward force.
Taking upward as positive
$F_{net} = C - W$
$C = 70\ (9.81 + 0.2)$
$C = 700.7 = 700$ N



5 **Ans: B**

For A and C, three forces are not concurrent (concurrent: lines of action of forces pass through a common point), hence net torque not zero
For C and D, forces do not formed closed triangle, hence net force not zero

For B, the three forces are concurrent and form a closed triangle



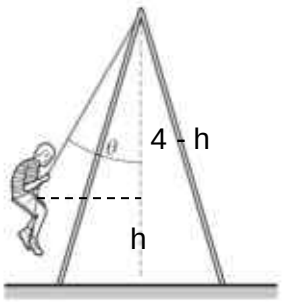
6 **Ans: C**

By the horizontal component and using COM,
10 (0.3) + 0 (1.2) = v (1.2 + 0.3)
v = 2 m s^{-1}
Final KE = ½ (1.5) $(2)^2$ = 3.0 J

7 **Ans: C**
Taking moments about hinge,
5(40g) = 2F where F = kx
5(40 x 9.81) = 2 (10 000) x
X = 0.0981 m = 9.81 cm = 9.8 cm

8 **Ans: A**

KE at lowest point = 0.5(50)$(3)^2$ = 225 J
Change in height of boy, *h* = 225/mg = 0.4587 m
cos θ = (4-h)/4
θ = 28°



9 **Ans: B**

Avg P = total change in KE/total time
= 0.5$\Delta mv^2/\Delta t$
= 0.5(100 x 10^6)$(12)^2$/(10x60)
= 1.2 x 10^7 W

10 **Ans: D**

Its linear velocity is changing as the direction is changing.

Linear acceleration is the vector sum of tangential acceleration and centripetal acceleration. Since tangential acceleration is zero for uniform circular motion, the linear acceleration is equal to the centripetal acceleration which is changing because its direction is changing (neither zero nor constant).

11 **Ans: D**

By COE from point P to Q, $\Delta E_p = \Delta E_k$

$mg\ (20 - 18) = \frac{1}{2}\ mv^2$

$v = 6.26\ \text{m s}^{-1}$

$\Sigma F \Rightarrow W - R = mv^2 / r$

$R = W - mv^2 / r = mg - mv^2 / r = 820\ \text{N}$

12 **Ans: D**

It is due to net force acting on any body being directed towards X.

For A, the gravitational potential increases rapidly (due to inverse relation) with distance from the surface of a body. Therefore the net gravitational potential at X cannot be a minimum.
For B, as the net force acting on any body is directed towards X, the direction of the net force is different for the four bodies, depending on the position of the body relative to X.
For C, the gravitational field strength of the individual bodies at X are of the same magnitude, and the directions result in a vector sum of zero, hence the net gravitational field strength is zero.

13 **Ans: A**

For few hundred metres above Earth's surface, $\Delta U \approx mgx$

14 **Ans: A**

Period is not affected by amplitude
(period of spring-mass system depends on mass of object, m, and spring constant, *k*;

$k = m w^2 = m(\frac{2\pi}{T})^2)$

Total energy, E_T = max epe, $E_p = \frac{1}{2} k x_o^2$ (where x_o = amplitude)
Or Total energy, E_T = max ke, E_k
$= \frac{1}{2} m v_o^2$
$= \frac{1}{2} m w^2 x_o^2$ (where v_o = max. velocity = $w x_o$)

therefore Total energy is proportional to (amplitude)^2 i.e. $E_T \propto x_o^2$

$$\frac{E}{E_{new}} = \frac{X^2}{\left(X/2\right)^2}$$

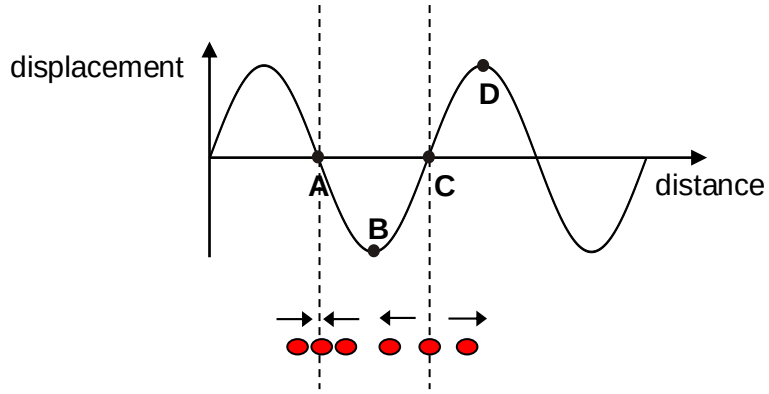
$$E_{new} = \frac{E}{4}$$

15 **Ans: A**

The changing E field of the EM wave forced the electron into oscillation at frequency 200 kHz

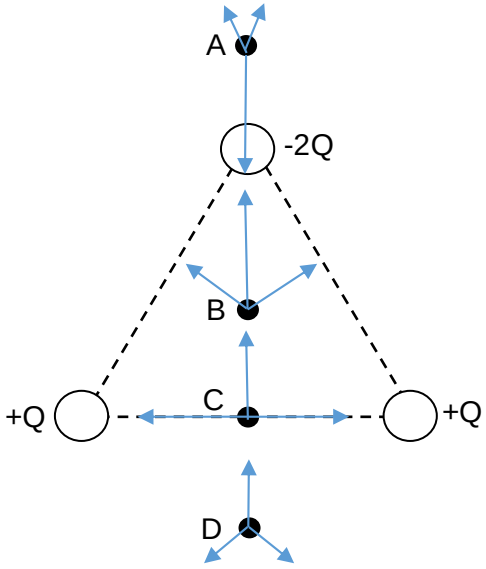
max F = m a_{max}
$qE_o = mw^2 x_o = m (2\pi f)^2 x_0$

$x_0 = 5.6 \times 10^{-4}$ m

16	**Ans: B** Let the final temperature be T. thermal energy gained by cube X = thermal energy lost by cube Y $m_X c\Delta\theta_X = m_Y c\Delta\theta_Y$ $\rho V_X c(T - 25) = \rho V_Y c(75 - T)$, where V_X and V_Y are the volumes of cube X and Y $\rho(\sqrt{2}L)^3 c(T - 25) = \rho L^3 c(75 - T)$, where L is the length of each side of Y $2\sqrt{2}\,(T - 25) = 75 - T$ $T = 38.06 = 38$ °C
17	**Ans: D** A, B and C will only increase the frequency of elastic collisions but not the speed of the molecules. Only D will result in the increase in the average speed of the molecules as energy is transferred to the molecules as the piston compresses the gas.
18	**Ans: C**  A is compression, C is rarefaction.
19	**Ans: C** Slit separation $a = \lambda D/x$ For small angles in radian, $\tan\theta \approx \theta$. Hence, $x/D = 5 \times 10^{-4}$ $a = \lambda D/x = 7.0 \times 10^{-7} / (5 \times 10^{-4}) = 1.4 \times 10^{-3}$ m
20	**Ans: C** Path difference = 4.0 – 1.0 = 3.0 m = 1½ λ Since sources are in anti-phase, waves will arrive at P in phase. Constructive interference occurs, so amplitude of resultant wave = $A + 2A = 3A$
21	**Ans: B** Using $n\lambda = d\sin\theta$, $n(5.40 \times 10^{-7}) = d\sin\theta$ …… eqn 1 $(n + 1)(4.05 \times 10^{-7}) = d\sin\theta$ …… eqn 2 Solving eqn 1 and 2, $d = 3.24 \times 10^{-6}$ m Lines per metre = $1 / d = 3.09 \times 10^5$

22 **Ans: D** **D**

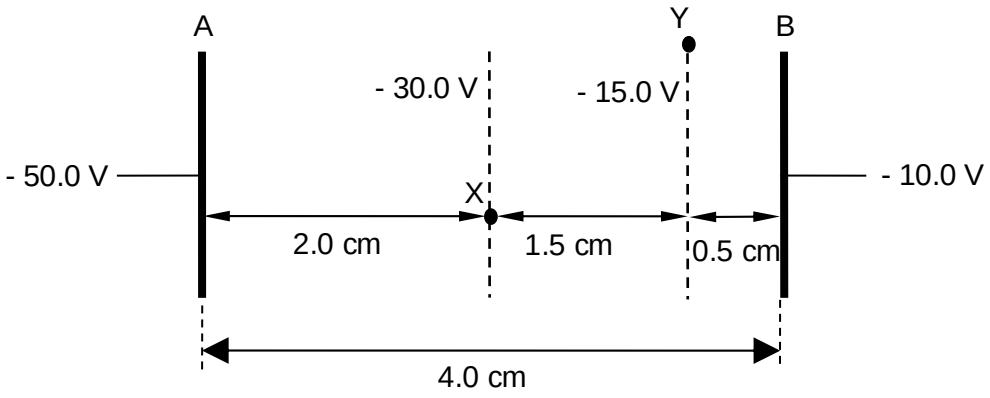
The forces due to the charges at different positions are shown.



$F \alpha \frac{Qq}{r^2}$

At A, the force due to the negative charge -2Q is always much larger than the sum of force due to the 2 positive charges +Q. Hence, there is a net downward force.

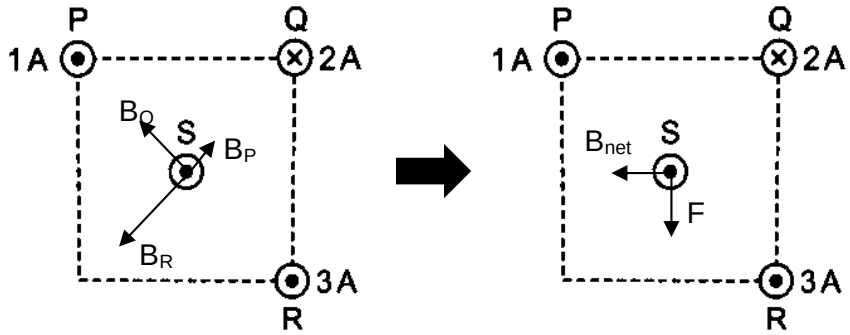
23 **Ans: A** **D**



For parallel plate, the E field is uniform and the potential is evenly distributed.
Potential at X is -30.0 V
Potential at Y = -15.0 V
p.d between X and Y is 15.0 V

or

p.d between X and Y = $\frac{1.5}{4.0}$ x (-10.0 – (-50.0)) = 15.0 V

24	**Ans: B** Graph does not pass through origin, so it does not obey Ohm's law. When V = 1.5 V, R = V / I = 1.5 / 0.025 = 60 Ω.	**A**
25	**Ans: A** W = QV = (It)V 12 = I (15) (20) I = 0.040 A	**E**
26	**Ans: C** In C, the resistor and lamp are connected in parallel to the power supply, hence the potential difference across the resistor (the portion which current is flowing through) and lamp will be equal to the terminal potential difference (emf in this case assuming no internal resistance) of the power supply. Hence the potential difference across the lamp cannot be varied.	**A**
27	**Ans: B** Using RHGR to obtain the individual magnetic field vectors and find the resultant. Then use FLHR to determine the force on wire S.  Or, determine force of each wire on S, then final resultant F.	**A**
28	**Ans: C** The angle between the magnetic field and current remains at 90°.	**A**
29	**Ans: A** The magnetic flux density *B* produced by the solenoid at the ring's position is given by: $B = kI$ where *k* is a constant $E = -\frac{d\Phi}{dt}$ $= -NA\frac{dB}{dt}$ $= -NAk\frac{dI}{dt}$ Hence the induced emf is the negative gradient of I-t graph.	**D**

30	**Ans: C** Average e.m.f = $\frac{-\Delta\Phi}{\Delta t} = -\frac{NBA\cos 150° - NBA\cos 30°}{t}$ $= -\frac{(10)(0.15)(1.2)(\cos 150° - \cos 30°)}{2.0}$ = 1.6 V	**D**
31	**Ans: B** When the potential at X is higher than the potential at Y, the total resistance in the circuit is R_1. Current flows from X to Y. Similarly, when the potential at Y is higher than the potential at X, the total resistance in the circuit increased to $R_1 + R_2$. Current flows from Y to X (opposite direction) and has a lower peak value than when it flows from X to Y.	**A**
32	**Ans: B** $V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{\frac{100^2}{4}} = \frac{100^2}{4} = 50 = \frac{1}{2}V_0$ For half-sinusoidal wave, rms value equals half of peak value.	**E**
33	**Ans: D** c = fλ. Metal Q has a smaller threshold wavelength, corresponding to a larger threshold frequency, than metal P. D is correct. Gradient of graph is not a constant, so A is incorrect. ϕ = hf_0. Metal P has a smaller threshold frequency, so smaller work function. B is incorrect. Intensity of radiation does not affect maximum KE of emitted electrons, or stopping potential. C is incorrect.	**A**
34	**Ans: D** Consider a one metre length of the laser beam, time taken t for photons to travel 1 metre, $t = \frac{1}{c}$ $P = \frac{E}{t} = \frac{nhf}{t} = cnhf$, so $n = \frac{P}{chf}$	**A**
35	**Ans: A** Using the equation $T \propto exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$ Due to the exponential factor, a smaller mass will significantly reduce the transmission coefficient. A proton is much more massive (approx. 2000 times) than electron, T will reduce by $e^{-\sqrt{2000}} \approx 4 \times 10^{-20}$ times.	**E**
36	**Ans: D** The conductivity of extrinsic semiconductors increases with temperature and amount of impurities. A and B are true. When an electron is excited from the donor level to the conduction level, the impurity atom loses its fifth valence electron, so it carries a net positive charge. C is true. The semiconductor here is n-type, so it does not have an acceptor level. D is false. D applies only for p-type semiconductors.	**E**

37	**Ans: C** From diagram, when R is forward biased, S is reversed biased, so no current. Only options C and D show a diagram of S that has no current, ie no moving charges. Forward biased in R means that conventional current is to the left, so its right is at a higher potential than its left. For forward biased, the p-type must be connected to the higher potential, so p-type is on the right. Majority charge carriers in p-type are holes, so holes should be seen on the right side of R. C is correct and D is wrong.	**D**
38	**Ans: C** Mass of uranium = 235 u = 235 x 1.66 x 10^{-27} $\approx 10^{-25}$ kg	**A**
39	**Ans: B** All other statements are true but they are not drawn from alpha scattering experiment.	**A**
40	**Ans: C** Energy released in rxn = 8.6x98 + 8.4x135 – 7.6x235 = 190 MeV	**E**

NAME: _____ CLASS: _____ INDEX: _____

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

PHYSICS

9646/1
Paper 1
29 AUGUST 2016
1 h 15 mins

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name, tutorial group and index number on this cover page.

Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet),
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are a total of **40 Multiple Choice Questions (MCQs)** 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 Answer Sheet (OMR sheet) provided.

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.
Calculators may be used.

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 The Van Der Waal's equation is used to describe the pressure, *P*, volume, *V*, and temperature, *T*, of a real gas,

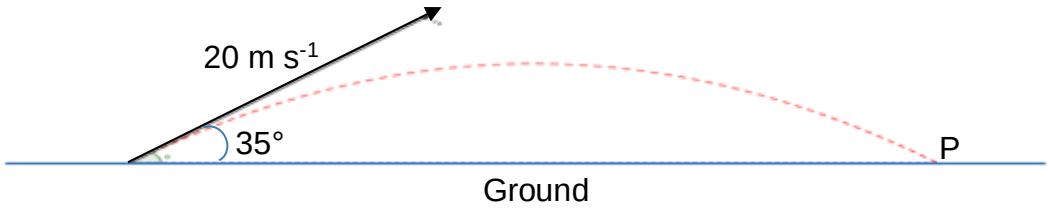
$$\left(P+\frac{n^2a}{V^2}\right)(V-nb)=nRT$$

where *n* is the number of moles of gas present and *R* is the universal gas constant. *a* and *b* are empirical constants.

What are the units of *a* and *b* respectively?

	Unit of *a*	**Unit of *b***
A	Pa m^6 mol^{-2}	m^3 mol^{-1}
B	mol^2 Pa^{-1} m^{-6}	mol m^{-3}
C	J m^2 mol^{-2}	J m^3 mol^{-1}
D	mol^2 J^{-1} m^{-2}	mol J m^{-3}

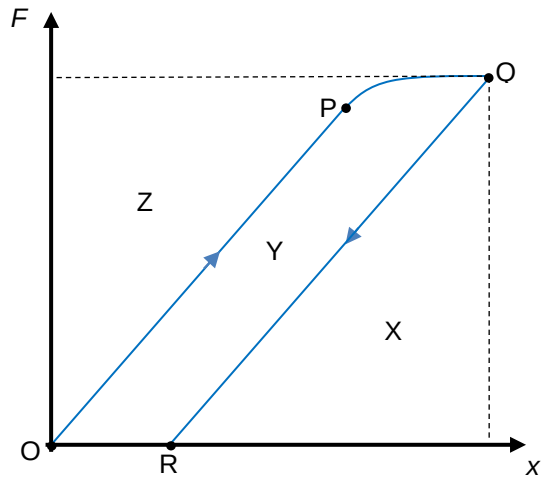
2 A student throws a stone 35° above the ground at an initial speed of 20 m s^{-1}. It travels in a projectile motion until it hits the ground at P with the same speed.



What is the magnitude of the change in velocity of the stone just before hitting the ground at P?

A 0.0 m s^{-1} **B** 20 m s^{-1} **C** 23 m s^{-1} **D** 33 m s^{-1}

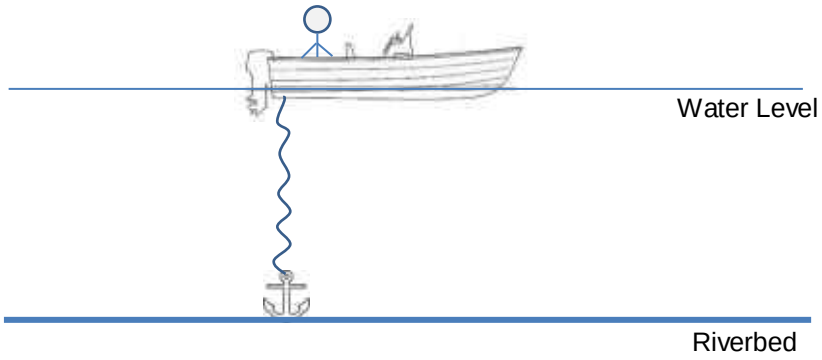
3 A metal wire is stretched by a varying force *F*, causing its extension *x* to increase as shown by the line OPQ on the graph. The force is then gradually reduced to zero and the relation between the force and extension is indicated by line QR.



Which area represents the elastic potential energy stored in the wire at Q?

A X **B** Y **C** Z **D** X + Y

4 The anchor of a small boat is initially completely submerged in water and resting on the riverbed.



What happens to the water level with respect to the boat when the fisherman first pulls the anchor up and when the anchor is finally on the small boat? Assume that the rope tied to the anchor is of negligible mass and volume.

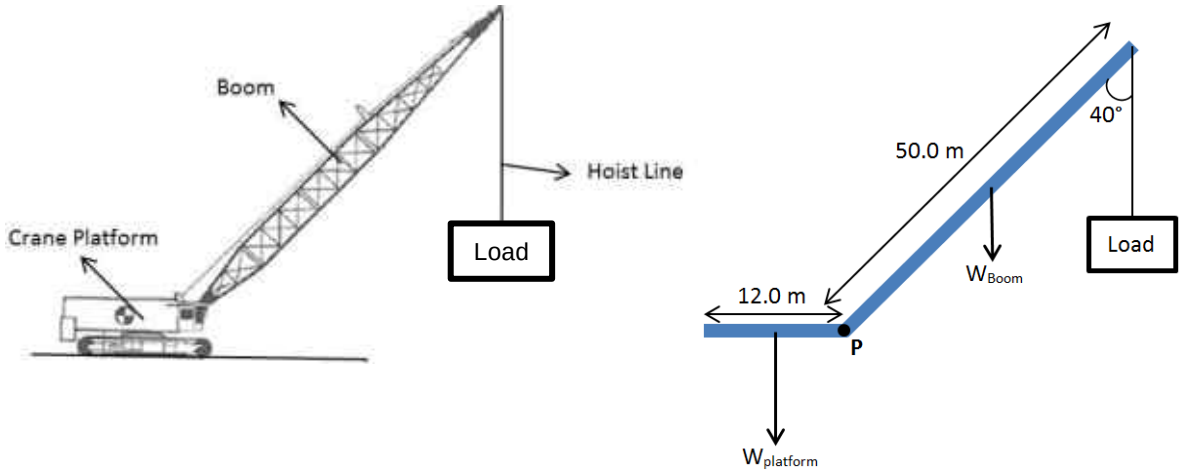
A The water level decreases when the fisherman first pulls the anchor up and then increases when the anchor is finally on the small boat.

B The water level increases when the fisherman first pulls the anchor up and then decreases when the anchor is finally on the small boat.

C The water level increases when the fisherman first pulls the anchor up and then increases further when the anchor is finally on the small boat.

D The water level decreases when the fisherman first pulls the anchor up and then decreases further when the anchor is finally on the small boat.

5 A crane starts to lift a load of 5.80×10^4 kg load from the ground.

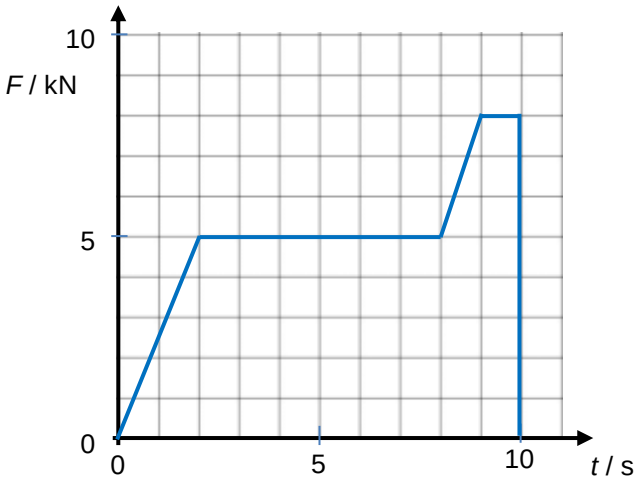


The diagram on the right is a simplified schematic representation of the crane and load on the left.

If the platform has a uniform mass of 4.00×10^5 kg and the boom has a uniform mass of 4.00×10^4 kg what is the maximum mass that the crane can lift vertically at constant speed at the end of the boom without the crane toppling over at point P?

A 2.80×10^4 kg **B** 4.27×10^4 kg **C** 4.40×10^4 kg **D** 5.47×10^4 kg

6 The following graph describes the variation of the resultant force *F* on an object of mass 2500 kg with time *t* until 10 s.



If the object is initially at rest when $t = 0$ s, what is the object's speed at $t = 8$ s?

A 14 m s^{-1} **B** 16 m s^{-1} **C** 18 m s^{-1} **D** 20 m s^{-1}

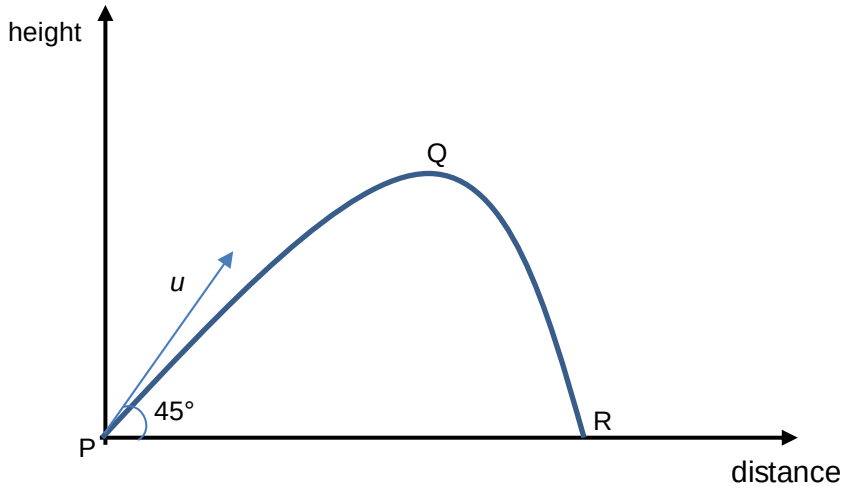
7 An object falls freely from rest vertically to the ground. The effects of air resistance on the object are negligible.

The object travels 60 % of the total vertical distance to the ground in the last second of its fall.

What is the total vertical distance?

A 1.8 m **B** 2.1 m **C** 36 m **D** 71 m

8 An object is projected with a certain speed *u* at an angle of 45° to the horizontal from the ground at point P. It travels through air with significant drag force on it, reaches the maximum height at Q, falls and hits the ground at a certain distance away at R.



Which of the following statement is true?

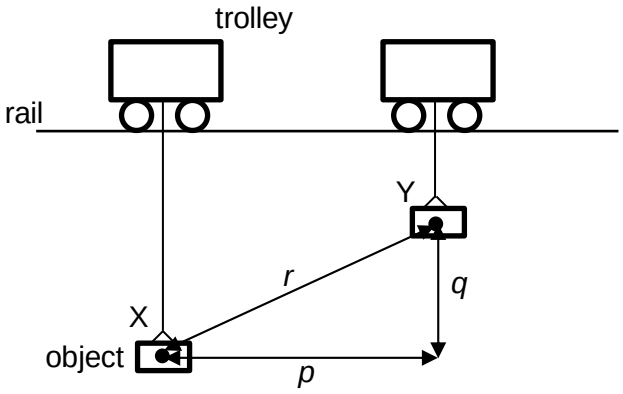
A The time taken for the object to travel from P to Q is more than the time taken for it to travel from Q to R.

B The time taken for the object to travel from P to Q is less than the time taken for it to travel from Q to R.

C The time taken for the object to travel from P to Q is the same as the time taken for it to travel from Q to R.

D The time taken for the object to travel from P to Q can be the same as or more or less than the time taken for it to travel from Q to R, depending on speed *u*.

9 An object of weight *W* hangs from a trolley that runs along a rail. The trolley moves horizontally through a distance *p* and simultaneously raises the object through a height *q*.



As a result, the object moves through a distance *r* from X to Y. It starts and finishes at rest.

Which of the following statements about the object during this process **must** be correct?

A The work done on the object is *Wr*.

B The net work done on the object is 0.

C The gravitational potential energy at Y is *Wq*.

D The increase in kinetic energy of the weight is *W(p + q)*.

10 The data below are taken from a test of a petrol engine for a motor car.

power output	150 kW
fuel consumption	20 litres per hour
energy content of fuel	40 MJ per litre

Which expression will evaluate the efficiency of the engine?

A $\dfrac{150 \times 10^3}{40 \times 10^6 \times 20 \times 60 \times 60}$

B $\dfrac{150 \times 10^3 \times 60 \times 60}{20 \times 40 \times 10^6}$

C $\dfrac{150 \times 10^3 \times 40 \times 10^6 \times 20}{60 \times 60}$

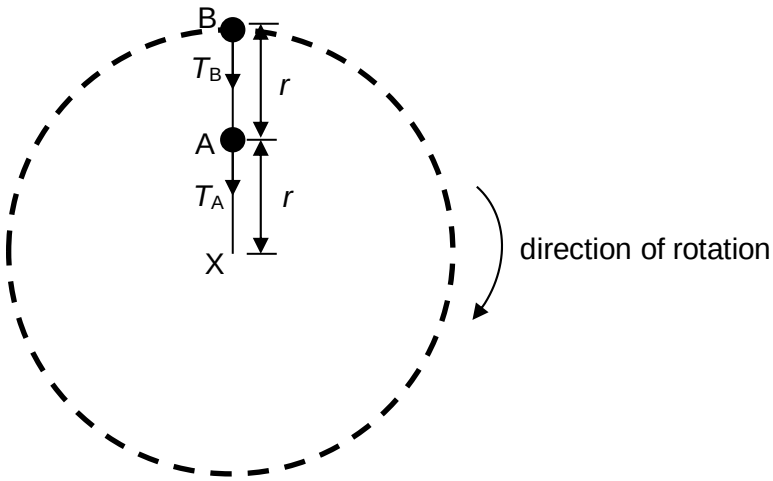
D $\dfrac{150 \times 10^3 \times 20}{40 \times 10^3 \times 60 \times 60}$

11 Two toy cars are set to run round a circular track of radius 80 m. Each of them moves at a constant speed. At time *t*, car A overtakes car B. 4 minutes later, car A passes B again for the second time.

What is the period of car A, if the period of car B was 60 seconds?

A 15 s **B** 48 s **C** 120 s **D** 240 s

12 Two spheres A and B of equal mass, *m*, are attached on a string which moves in a vertical circular motion. A is at a distance *r* while B is 2*r* away from the end of the string X as shown in the figure below.



The tensions in each part of the strings are T_A and T_B respectively.

Which of the following statements about the forces acting on objects A and B are correct?

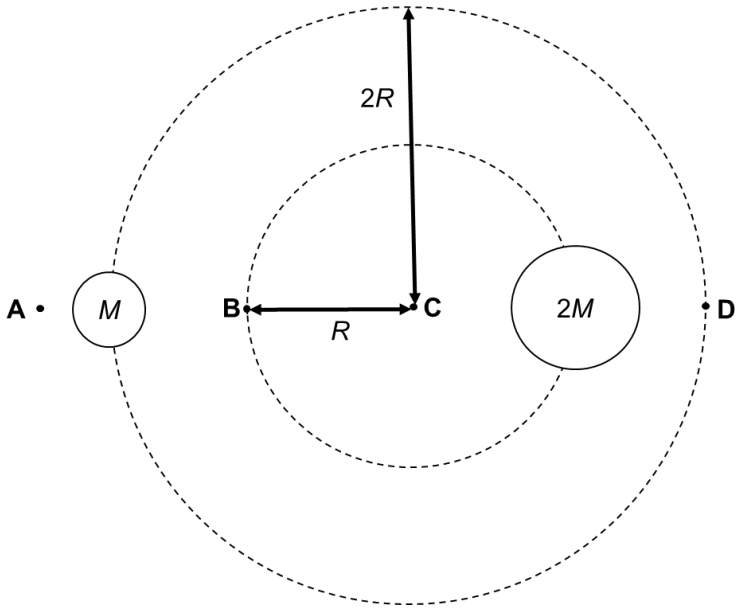
A The magnitude of T_A and T_B are always constant.

B Throughout the motion, the net force acting on sphere A is only T_A.

C For the objects to execute circular motion T_B can have a magnitude of zero.

D The magnitude of T_A and T_B are always equal as they are action reaction forces.

13 Two binary stars of masses M and $2M$ revolve about their common centre of mass in orbits of radius $2R$ and R respectively.



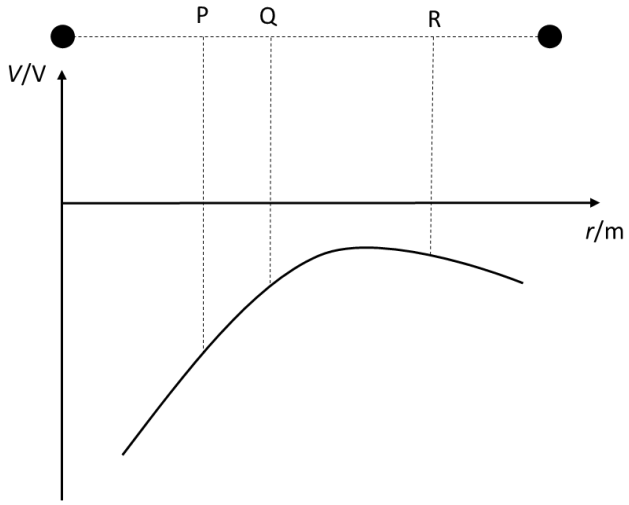
At which point does the gravitational field strength have the lowest magnitude?

14 On October 19 2016, the spacecraft *Juno* will enter into a circular polar orbit with a period of 14 days around the planet Jupiter which has a mass of 1.90×10^{27} kg.

What is the radius of *Juno's* orbit?

A 8.64×10^{4} m **B** 1.67×10^{9} m **C** 6.29×10^{17} m **D** 4.69×10^{27} m

15 Two charges are placed in free space. The variation of the electric potential *V*, with the distance *r* from the left charge along the line joining the centres of the charges is shown below.



Which of the following statements is true?

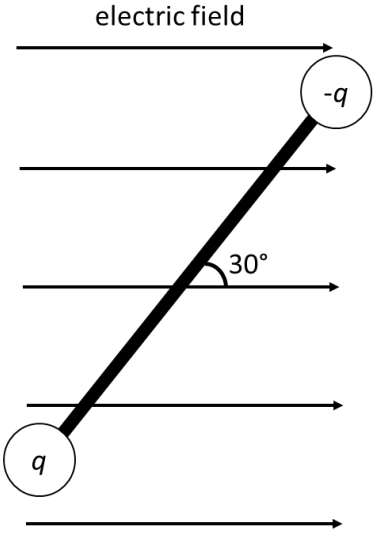
A Any charge placed at point P will experience a resultant force towards the left.

B The electric field strength at point Q is larger than the electric field strength at P.

C Net positive work needs to be done by an external agent to move a negative charge from point R to point P.

D A positive charge at P has more electric potential energy as compared to an identical positive charge placed at R.

16 Two charges of electric charge *q* and –*q* connected by a light electrically insulated rigid rod of length *L* are placed in a uniform electric field of electric field strength *E* as shown in the figure.



Which of the following is the correct expression for the torque due to the couple?

A $\frac{qEL}{2}$

B qEL

C $2qEL$

D q^2E^2L

17 An object moving in simple harmonic motion has a maximum velocity v_0 and an amplitude x_0.

What is its velocity, in terms of v_0, when it is at a distance $0.25x_0$ from its amplitude position?

A $0.13v_0$

B $0.25v_0$

C $0.66v_0$

D $0.75v_0$

18 Some doors use a spring system to ensure the door closes again after it is opened. These springs are usually damped.

If the spring used causes critical damping in the door, which of the following will happen when the door is opened?

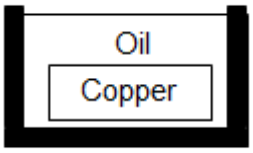
A The door will quickly swing shut without oscillating.

B The door will continue to swing back and forth for a long time.

C The door will take a long time to swing shut without oscillating.

D The door will swing back and forth, but will come to a stop eventually.

19 A copper block at 500 °C is cooled in an oil bath that was initially at 20 °C.



Using the ratios below, calculate the temperature at thermal equilibrium. Assume no heat transfer with the surroundings and the container.

$$\frac{\text{density of oil}}{\text{density of copper}} = 0.110$$

$$\frac{\text{specific heat capacity of oil}}{\text{specific heat capacity of copper}} = 4.29$$

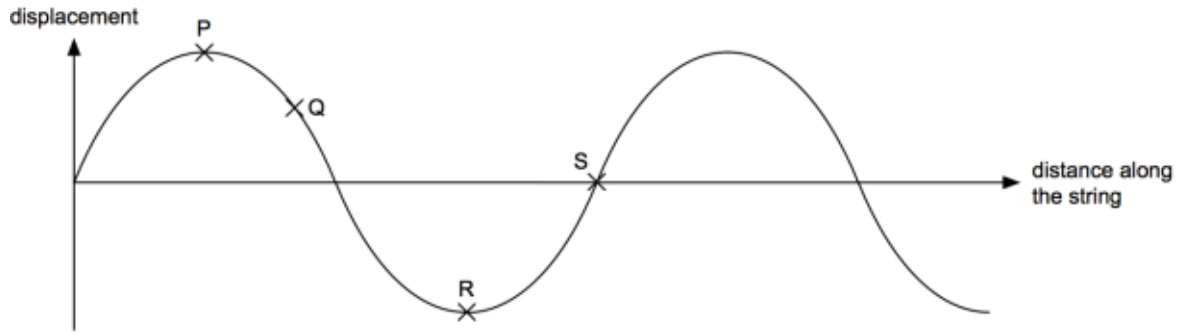
$$\frac{\text{volume of oil bath}}{\text{volume of copper}} = 10.0$$

A 41.6 °C **B** 104 °C **C** 160 °C **D** 416 °C

20 The temperature of an ideal gas is raised from 32.1 ºC to 40.5 ºC. What is the percentage increase in the r.m.s. speed of its gas particles?

A 1.4% **B** 2.8% **C** 12% **D** 13%

21 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?

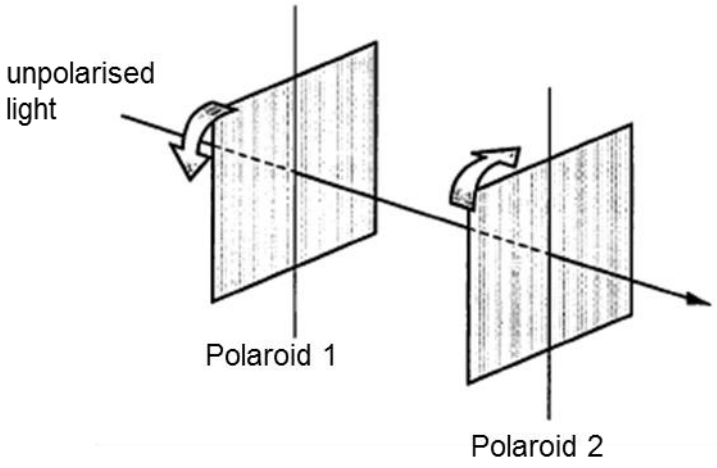
A The speed of Q is higher than S.

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.

22 The diagram shows a beam of initially unpolarised light passing through two Polaroid filters.

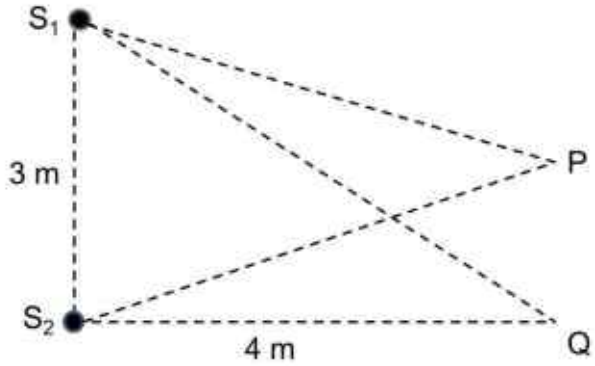


The transmitting axes of these filters are initially aligned. The two filters are now rotated through 360° in opposite directions in their own plane at equal speeds.

How many maxima of intensity occur in the light emerging from the Polaroid on the right?

A 2 **B** 3 **C** 5 **D** 9

23 Two sources of waves, S_1 and S_2, are situated as shown in the figure below. Individually, each source emits waves of intensity I.



Equidistant from S_1 and S_2, a detector at P registers a steady minimum wave intensity. The same detector registers the next steady minimum intensity when it moves to point Q. Which of the following statements is false about the two sources of waves?

A The two sources of waves are coherent.

B The two sources of waves have the same amplitude.

C The two sources of waves have a similar wavelength of 2 m.

D The two sources of waves have a phase difference of π radians.

24 Monochromatic light is incident normally on a diffraction grating and first order diffraction is observed at an angle of 28.6°.

Which of the following statements about the diffraction pattern produced by the grating is true?

A The second order image is observed at 57.2° and there is a total of 3 intensity maxima formed on the screen.

B The second order image is observed at 57.2° and there is a total of 5 intensity maxima formed on the screen.

C The second order image is observed at 73.2° and there is a total of 5 intensity maxima formed on the screen.

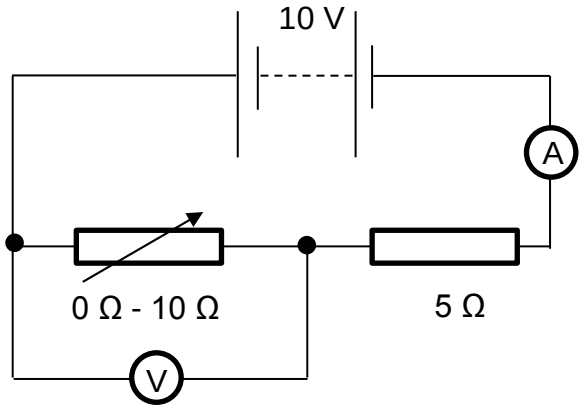
D The second order image is observed at 73.2° and there is a total of 7 intensity maxima formed on the screen.

25 The potential difference across an electrical component is 20 V. The time taken for charge carriers to move through this component is 15 s, and, in this time, the energy of the charge carriers changes by 12 J.

What is the electrical resistance of this component?

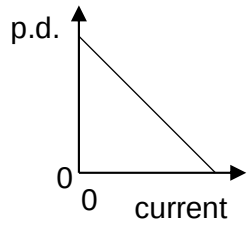
A 0.040 Ω **B** 0.80 Ω **C** 33 Ω **D** 500 Ω

26 A 10 V battery is in series with an ammeter, a 5 Ω fixed resistor and a 0 - 10 Ω variable resistor. A high-resistance voltmeter is connected across the variable resistor.

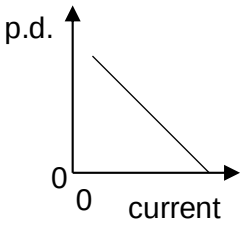


The resistance of the variable resistor is changed from zero to its maximum value.

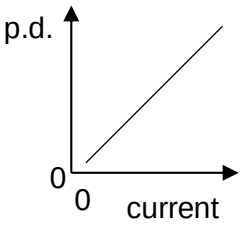
Which graph shows how the potential difference (p.d.) measured by the voltmeter varies with the current measured by the ammeter?



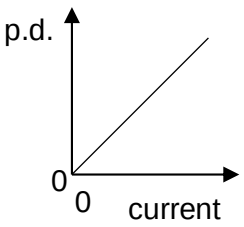
A



B

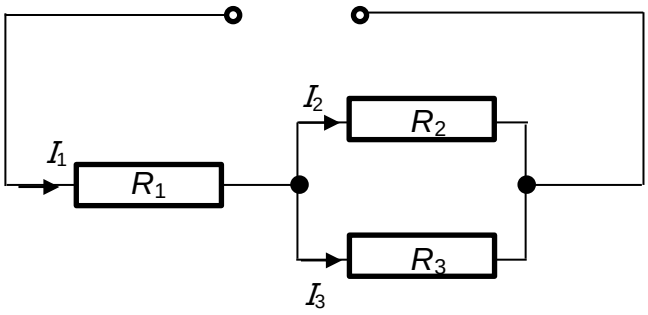


C



D

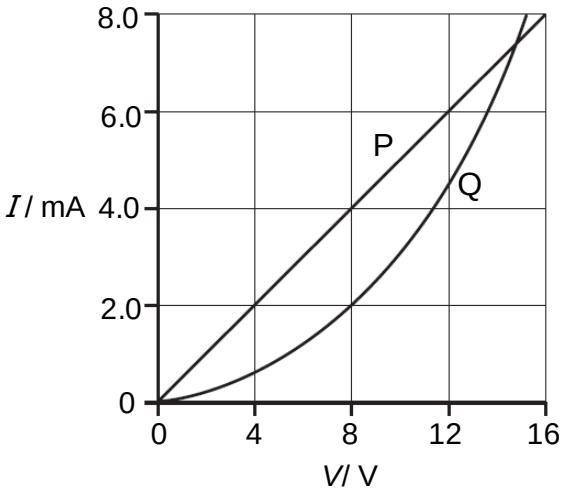
27 The circuit diagram shows three fixed resistors R_1, R_2 and R_3 connected to a power supply. The currents flowing through each of these resistors are I_1, I_2 and I_3 respectively.



Which of the following expression represents the ratio of $\frac{R_2}{R_3}$?

A $\frac{I_2}{I_3}$ **B** $\frac{I_1}{I_3}-1$ **C** $\frac{I_1}{I_2}-1$ **D** $1+\frac{I_3}{I_2}$

28 The *I*-V characteristics of two electrical components P and Q are shown below.



Which statement is correct?

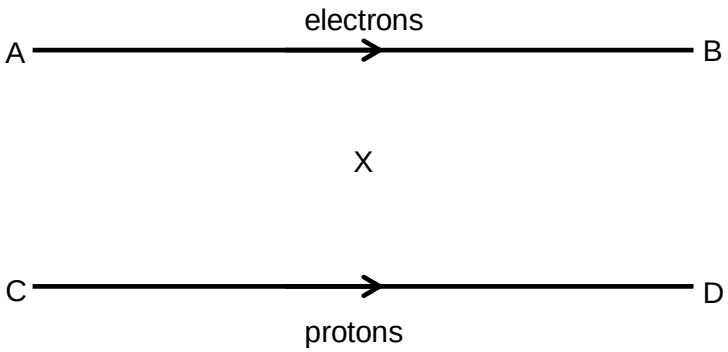
A P is a resistor and Q is a filament lamp.

B The ratio $\frac{\text{resistance of P}}{\text{resistance of Q}}$ is always less than 1.

C At 2.0 mA the power dissipated through Q is always twice that of P.

D At the point where the two lines intersect the resistance of Q is approximately twice that of P.

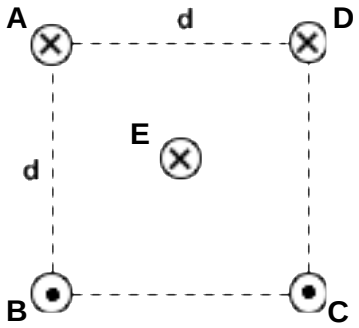
29 A beam of electrons in AB and another made out of protons in CD are parallel to each other.



The rate of proton flow in CD is twice that of the electrons in AB. What direction is the magnetic field at point X, which is equidistant from AB and CD?

A Towards AB **B** Towards CD **C** Into the page **D** Out of the page

30 Five straight and parallel wires are arranged as shown in the diagram below, and each carries a steady current I.



Which of the following statements incorrectly describes the above scenario?

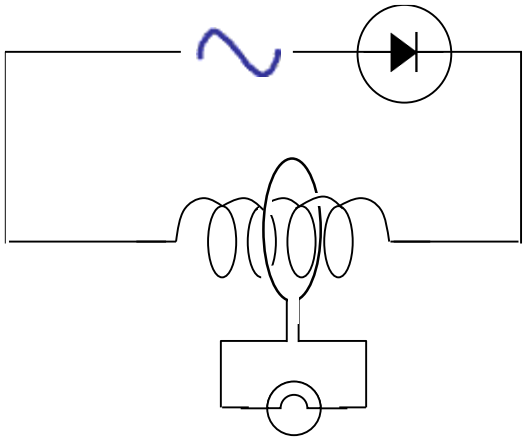
A The resultant force on wire E due to wires A, B, C and D is pointing towards line AD, perpendicular to AD.

B The resultant force on wire E due to wires B and C is pointing towards line AD, perpendicular to AD.

C The resultant force on wire E due to wires A and D is pointing towards line AD, perpendicular to AD.

D The resultant force on wire E due to wires B and D is pointing towards line AD, perpendicular to AD.

31 A circuit containing a circular loop of wire connected to a low power light bulb is positioned around a solenoid connected to a sinusoidal AC source and a diode as shown in the diagram below.



Which of the following statements is true?

A The light bulb lights up because the magnetic flux linkage through the loop varies with time.
.

B The light bulb lights up because the magnetic flux linkage through the loop reverses its direction every cycle.

C The light bulb does not light up because the magnetic flux linkage through the loop does not reverse its direction.

D The light bulb does not light up because the diode prevents current from flowing and thus producing any magnetic flux in the solenoid.

32 Two coils are linked by a soft iron bar as shown in Fig. A. A current source is connected to the primary coil. The primary current I_p varies with time as shown by the Fig. B.

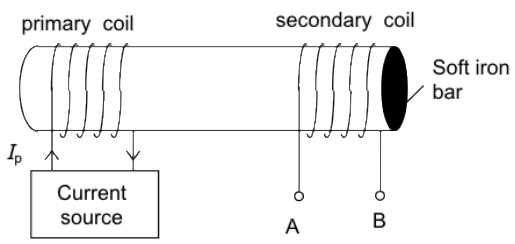


Fig. A

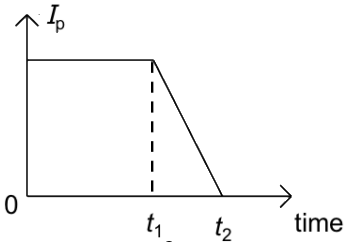
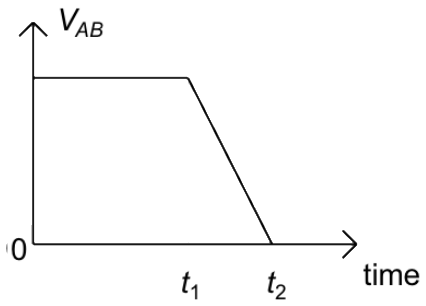


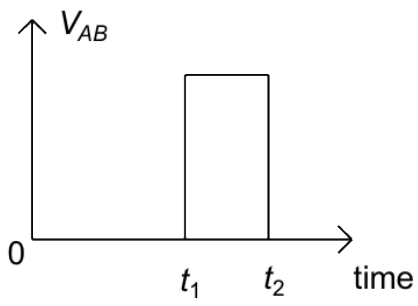
Fig. B

Which of the following sketches represents the variation of the voltage across the secondary coil V_{AB} with time?

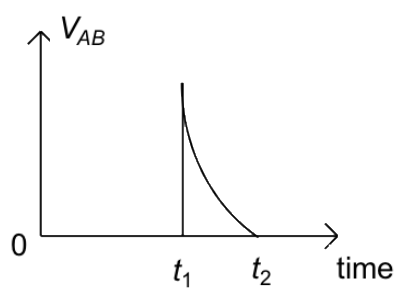
A



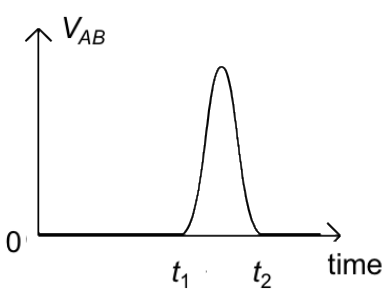
B



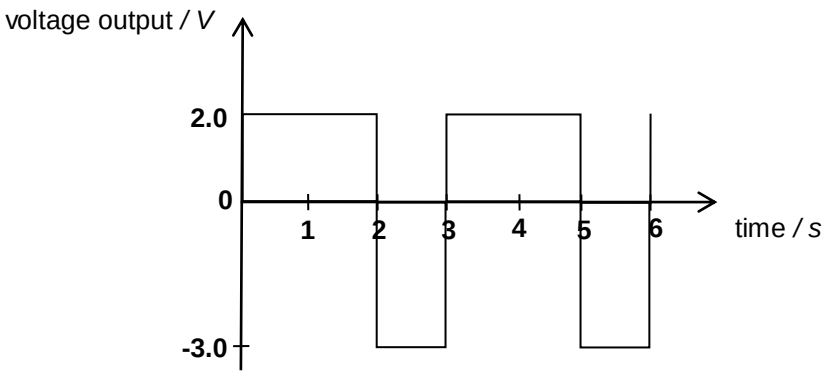
C



D



33 A 20 Ω resistor is connected to an AC power supply with a voltage output that varies from 2.0 V to -3.0 V as shown on the graph below.



What is the average heating power dissipated in the resistor?

A 0.083 W **B** 0.28 W **C** 0.43 W **D** 0.65 W

34 Which of the following statements about the wave-particle duality is true?

A The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that it is subatomic in size.

B The wave-particle duality suggests that every particle will have an associated wavelength when it moves, regardless of whether it has a mass or not.

C The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that they have a non-zero charge.

D The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that it is undergoing quantum tunneling.

35 The fastest recorded tennis serve was measured to have a speed of $(73.2 \pm 0.1)\ m\ s^{-1}$ and an average tennis ball has a mass of 58.0 g.

What is the minimum uncertainty of its position?

A 9.09×10^{-33} m **B** 1.24×10^{-35} m **C** 9.09×10^{-36} m **D** 1.24×10^{-38} m

36 Which of the following changes will increase the probability of a particle tunnelling through a potential barrier?

A Increasing the width of the potential barrier

B Increasing the height of the potential barrier

C Shooting particles of a smaller mass at the potential barrier

D Decreasing the energy of the particles incident on the potential barrier

.

37 Which of the following best describes the meaning of population inversion?

A Electrons are able to stay in such a state for a longer period.

B An atom in an excited state undergoes a transition to the ground state and emits a photon.

C The number of atoms at a lower energy state exceeds the number of atoms at a higher energy state.

D The number of atoms at a higher energy state exceeds the number of atoms at a lower energy state.

38 Which of the following statements about a semiconductor diode in forward bias is incorrect?

A Holes will move away from the p-n junction due to the external electric field.

B Electrons in the n-type semiconductor will cross steadily to the p-type semiconductor.

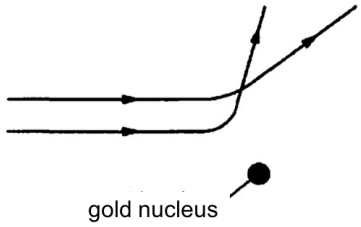
C The applied potential difference from the external source of e.m.f. opposes the junction potential.

D The n-type material of the diode is connected to the negative terminal of the external source of e.m.f.

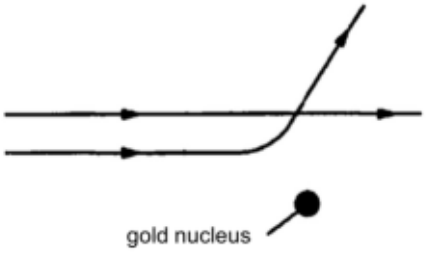
39 Two alpha particles with equal energies are fired towards the nucleus of a gold atom.

Which diagram could represent their path?

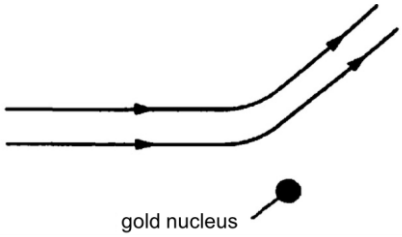
A



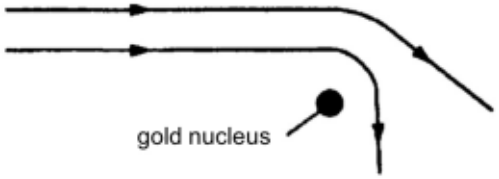
B



C



D



40 A newly prepared radioactive nuclide has a decay constant of 10^{-6} s^{-1}.

What is the approximate half-life of the nuclide?

A 1 hour

B 1 day

C 1 week

D 1 month

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CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME					
CLASS	**2T**	**INDEX NUMBER**			

PHYSICS
9646/2
Paper 2
23 August 2016
1 h 45 min

Additional Materials: Answer Papers

READ THESE INSTRUCTIONS FIRST
Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

A **maximum** of **2 marks** will be **deducted** for wrong significant figures and incorrect/lack of units.

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

DIFFICULTY		
L1	L2	L3

SKILL			
S1	S2	S3	S4

FOR EXAMINER'S USE	
Q1	/ 6
Q2	/ 11
Q3	/ 10
Q4	/ 6
Q5	/ 13
Q6	/ 14
Q7	/ 12
SF/UNITS	
TOTAL	/ 72

This document consists of **17** printed pages and **1** blank page

[Turn over]

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\pm \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

1 **(a)** A student wants to find the number of moles of nitrogen molecules in a reactor. In the high pressure reactor, a sample of nitrogen gas is kept at a pressure of $(5.0 \pm 0.2) \times 10^5$ Pa, with a volume of (100 ± 5) cm^3 and a temperature of (523 ± 5) K. The nitrogen in the reactor obeys the Ideal Gas Law, which is

$$PV = nRT$$

where P is the pressure of the gas, V is the volume of the gas, n is the number of moles of the gas, R is a constant and T is the temperature of the gas.

Determine the percentage uncertainty in calculating the number of moles of nitrogen molecules present in the reactor.

percentage uncertainty = …… % **[2]**

(b) Tempered glass screen protectors are made up of silicon dioxide (one silicon atom with two oxygen atoms) molecules.

Estimate the number of moles of silicon atoms in a 0.5 mm thickness tempered glass screen protector for a mobile phone. Show your working and reasoning clearly.

moles of silicon atoms = …… mol **[4]**

2 An archer shoots an arrow to hit a target board secured firmly on a stand as shown in Fig. 2.1. The point where the arrow is released is considered to be levelled with the target as measured from the ground.

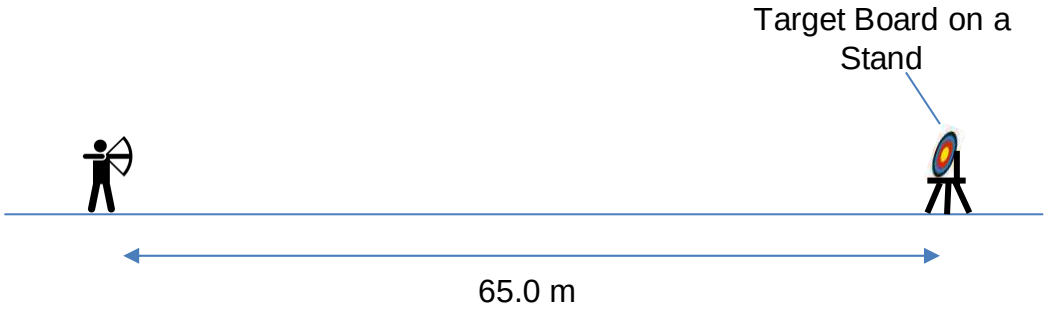

Fig. 2.1

The archer is standing still 65.0 m away from the target. The arrow has a mass of 880 g.

(a) (i) Explain why, in order for the arrow to hit the bull's eye, the archer has to aim the arrow at an angle above the target, and not directly at the target.

……..

……..

……..

…….. **[2]**

(ii) The arrow leaves the archer's bow at an angle less than 45° and with an initial velocity of 90.0 m s^{-1}. Determine the angle above the horizontal that the archer has to release the arrow such that it can hit the centre of the target.

You may find the following equation useful: $\sin 2x = 2\sin x \cos x$

angle above horizontal = …….. ° **[4]**

(b) The target board and its stand are resting on a frictionless ground. When the arrow strikes the target board, the arrow, target boards and stand move together as one body along the ground.

(i) Explain why the total momentum of the system consisting of the target board, stand and arrow in the horizontal direction along the ground is conserved before and after the arrow strikes the target board, whereas the total momentum of the system in the vertical direction is not conserved.

……..

…….. **[1]**

(ii) The target board and the stand have a total mass of 12.2 kg and are initially at rest before the arrow strikes them.

Determine the final speed of the arrow after it has struck the target board.

speed = …… m s^{-1} **[2]**

(iii) State the momentum of the archer along the frictionless ground immediately after the arrow is shot off from the archer. Explain your answer.

……..

……..

……..

…….. **[2]**

3 A loudspeaker operating at 86 Hz is producing a wave of wavelength 4.0 m.

For a particular instant of time,

Fig. 3.1 shows the graph of displacement, *s*, against distance, *x*, of the air particles.
Fig. 3.2 shows the regions of rarefaction and compression.
Fig. 3.3 shows the pressure variation with position along the wave at an instant of time.

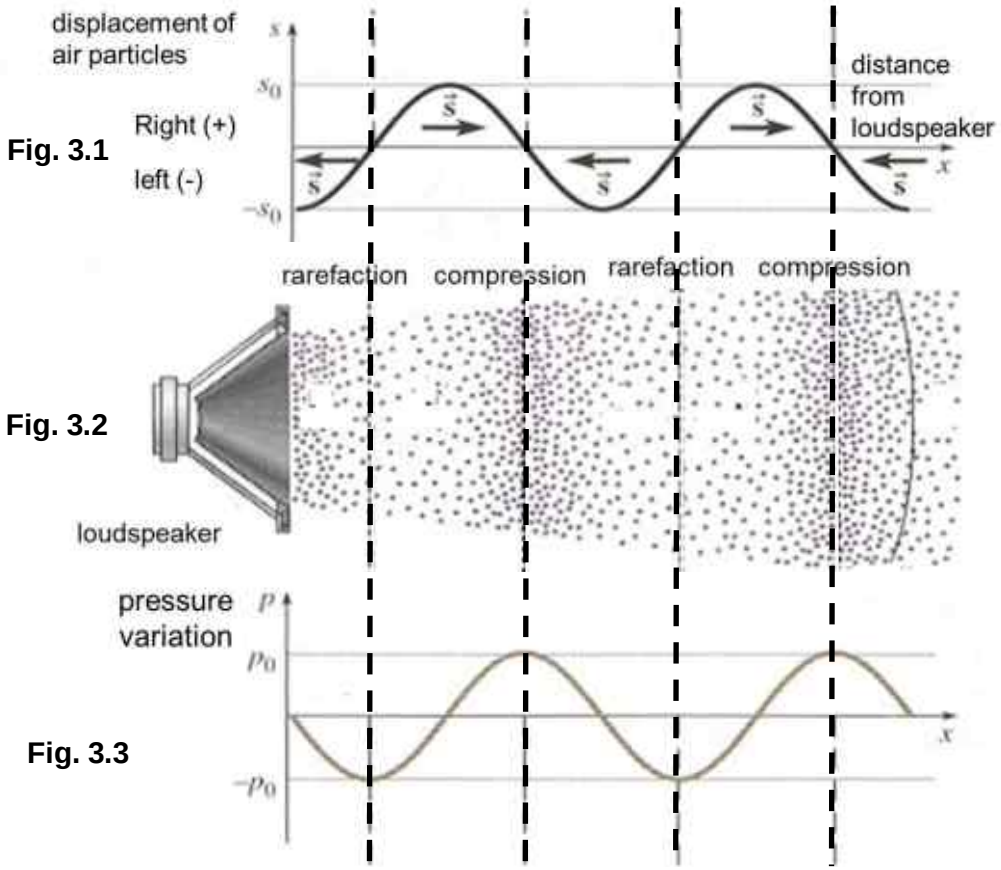

Fig. 3.1

Fig. 3.2

Fig. 3.3

(i) Determine the speed of the wave.

speed of wave = …….. m s^{-1} **[2]**

(ii) State the velocity of the rarefaction and compression regions. Explain your answer.

……

……

……

…… **[2]**

(iii) Another identical loudspeaker is now placed 20 m away to the right of the first loudspeaker shown in Fig. 3.2. Both loudspeakers are facing each other.

1. Explain the formation of the stationary (standing) wave between the loud speakers.

……

……

……

…… **[2]**

2. Determine the distance between any two consecutive nodes in the stationary wave formed.

distance = …….. m **[2]**

3. By describing the movement of molecules in a stationary sound wave, explain where the air pressure varies the least.

……

……

…… **[2]**

4 **(a)** Define *potential difference*.

……

…… **[1]**

(b) The circuit shown in Fig. 4.1 is used to compare potential differences of cells.

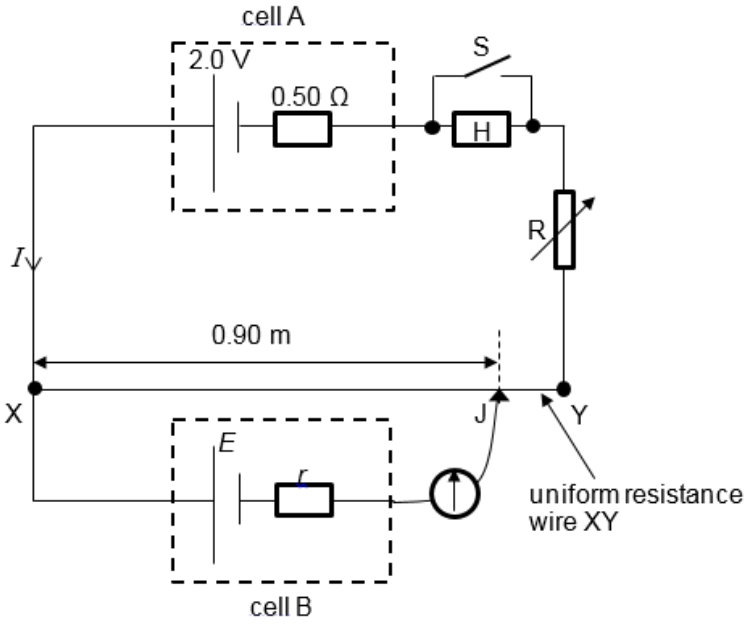

Fig. 4.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. When switch S is closed, the current through cell A is I. Cell B has e.m.f. E and internal resistance r.

The current through cell B is made zero when the movable connection J is adjusted such that the length of XJ is 0.90 m. The variable resistor R has resistance 1.5 Ω while the fixed resistor H has resistance 1.0 Ω

(i) Determine the value of E.

E = …….. V **[3]**

(ii) When switch S is opened, determine quantitatively if the balance length XJ exists for this setup with no change in the values of cell B.

[2]

5 Fig. 5.1 shows a simplified circuit diagram of the apparatus used in an experiment involving a photocell and a copper resistance wire XY to demonstrate the photoelectric effect. Scientists were particularly interested in the effects of the *intensity* and *frequency* of the electromagnetic radiation on the current (measured by the ammeter **A**) due to the emission of the photoelectrons.

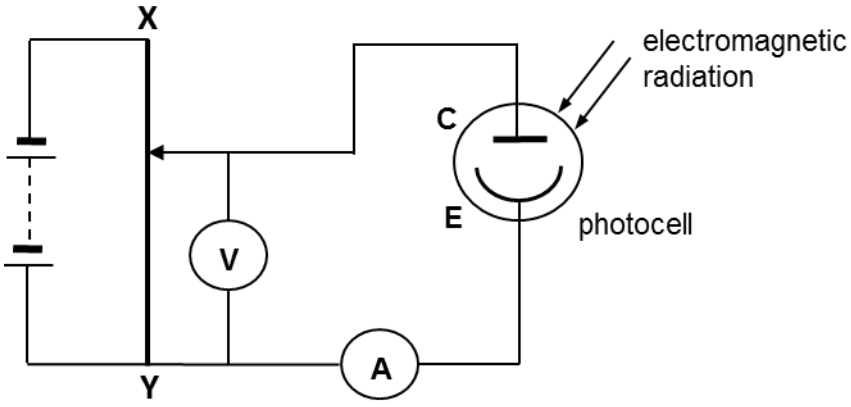

Fig. 5.1

(a) State what is meant by the *photoelectric effect.*

……...

……...

…….... **[1]**

(b) The Einstein's Equation for the photoelectric effect can be written as

$$E = \Phi + E_K$$

State the quantity represented by each symbol in the equation.

E :……..

……..

Φ :……..

……..

E_K :……..

…….. **[3]**

(c) For a given intensity and frequency of EM radiation, the following graph of current (I) against the applied potential difference (V) was obtained as shown in Fig. 5.2.

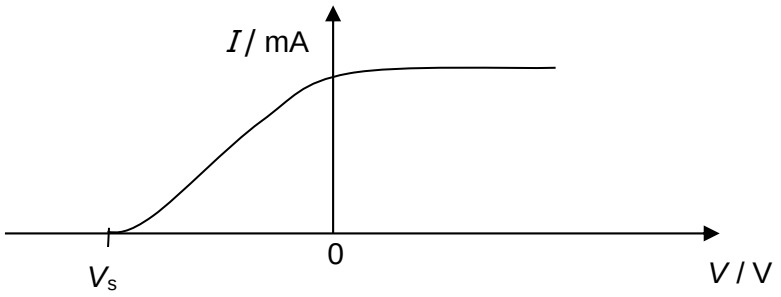

Fig. 5.2

Explain

(i) why there is a current registered in the ammeter even though the applied voltage across plates E and C is zero.

……

……

……

…… **[3]**

(ii) why there is no change in the current despite an increasing positive applied voltage when the current reaches a maximum value.

……

……

……

…… **[3]**

(iii) the changes, if any, in the graph in Fig. 5.2 when the copper resistance wire is now replaced with one made of gold.

……

……

……

…… **[3]**

6 Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 6.1 have been used since 1870, particularly for pumping water on farms.

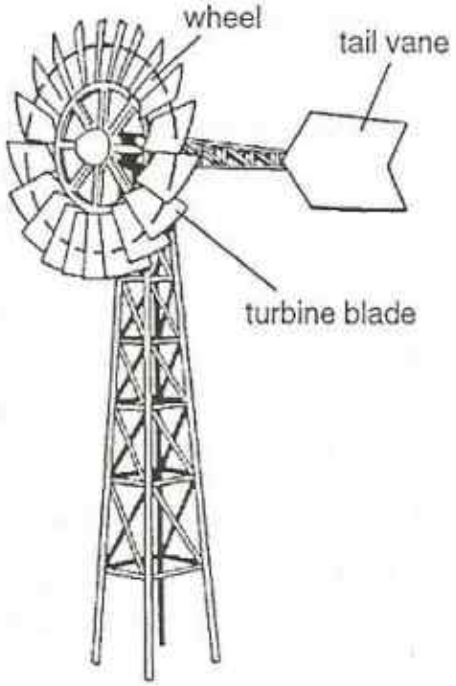

Fig. 6.1

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.

Fig. 6.2 shows the variation of P, the output power of windmills similar to that shown in Fig. 6.1 with the diameter of the wheel for different wind speeds, v.

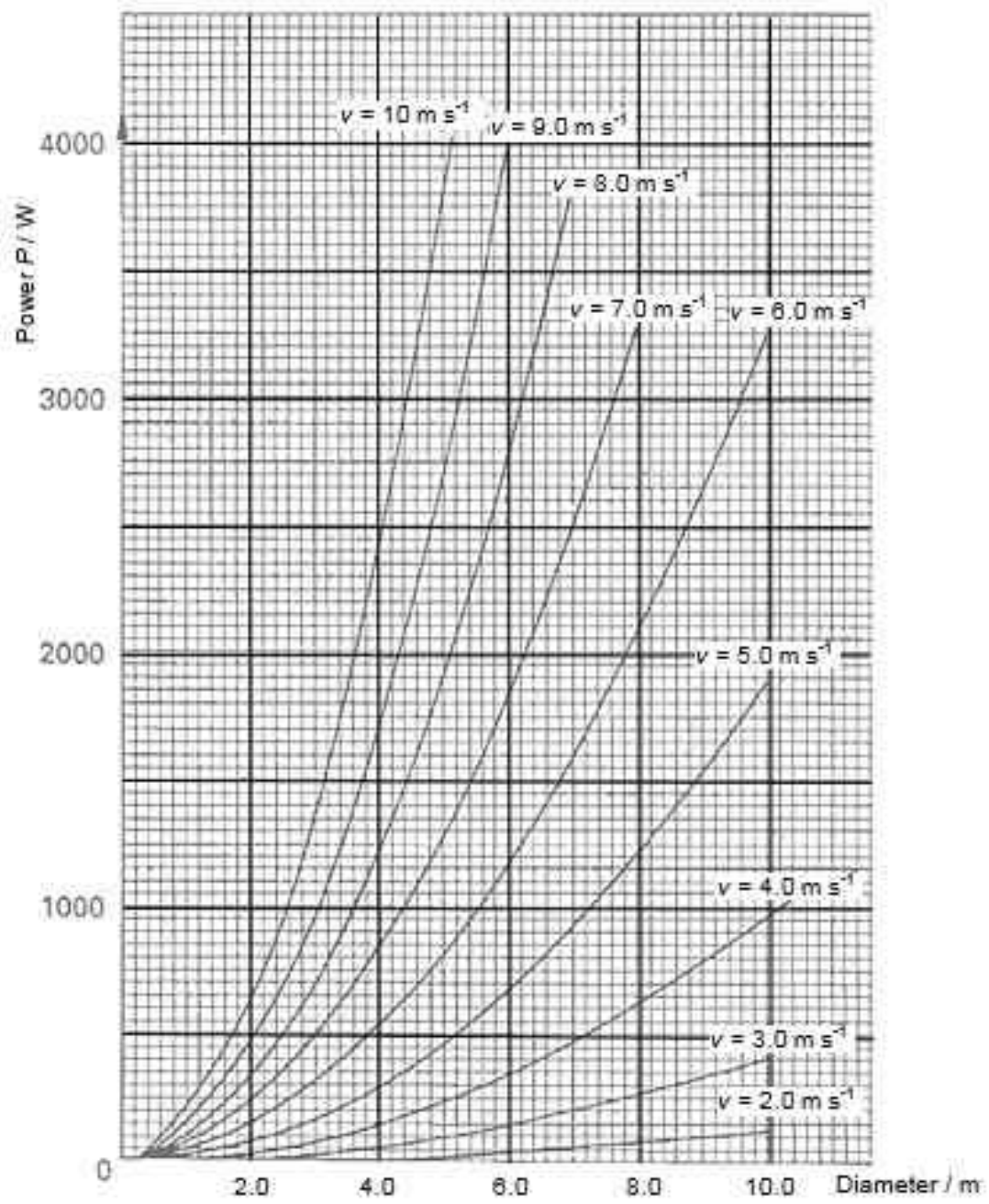

Fig. 6.2

(a) 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.

(i) Use Fig. 6.2 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 = ... **[1]**

(ii) The graph of lg (P / W) against lg (v / m s^{-1}) is plotted on Fig. 6.3.

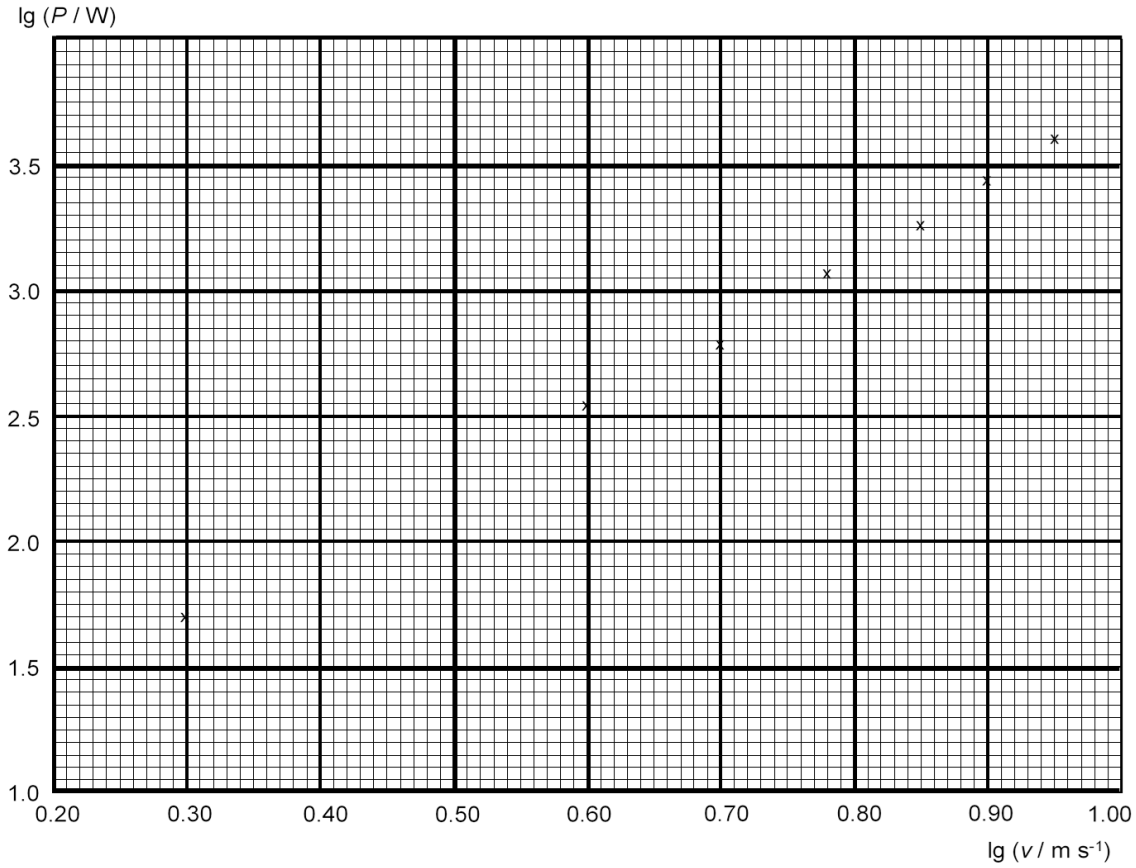

Fig. 6.3

On Fig. 6.3,

1. plot the point corresponding to a wheel diameter of 6.0 m and a wind speed of 3.0 m s^{-1} and **[1]**

2. hence, draw the line of best fit for the points **[1]**

(iii) Use the line drawn in **(c)(ii)** to determine the magnitudes of

1. the constant n, and

n =..... **[2]**

2. the constant, k.

k = ... **[2]**

(b) On a particular day, the wind speed is 8.0 m s^{-1}.

(i) Estimate the volume of air that reaches the 6.0 m diameter wheel of the windmill per second.

volume of air per second =……..m^3 s^{-1} **[2]**

(ii) The density of air is about 1.3 kg m^{-3}. Estimate the kinetic energy of the volume of moving air in **(b)(i)**.

kinetic energy of the air = …….. J **[2]**

(iii) Use Fig. 6.2 to find the fraction of the power from the moving air in **(b)(ii)** that is converted into useful power.

fraction of power = …… **[2]**

(c) State one other factor, besides wind speed and diameter of wheel that are likely to influence the output power of the windmill.

……

…… **[1]**

7 Gamma ray (γ-ray) is a type of ionising radiation. The absorption of γ-ray as it passes through a metallic material increases as the thickness of the material increases. The count rate of the γ-ray, *C*, penetrating through a material depends on the thickness *d* of the material.

You are provided with a Cobalt-60 source, a Geiger-Müller Tube connected to a datalogger that measures the total number of counts in a fixed time period and a number of lead slabs with standard business card dimensions to act as absorbers of γ-rays. Cobalt-60 is a radioactive source that emits both β rays and γ-rays at the same time. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between *C* and *d*.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay special 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 *C* and *d* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment. **[12]**

Diagram

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.....

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CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME					
CLASS	**2T**	**INDEX NUMBER**			

PHYSICS

9646/3
PAPER 3
25 August 2016
2 hours

Additional Materials: Answer Papers

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
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 in **Section A**, and **TWO** out **three** questions in **Section B.**

Circle the question number of the questions that you have attempted in **Section B** in the summary table at the bottom of this page.

A **maximum** of **2 marks** will be **deducted** for wrong significant figures and incorrect/lack of units.

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

DIFFICULTY		
L1	L2	L3

SKILL			
S1	S2	S3	S4

FOR EXAMINER'S USE	
Q1	/ 6
Q2	/ 6
Q3	/ 6
Q4	/ 12
Q5	/ 10
SECTION A	/ 40
Q6	/ 20
Q7	/ 20
Q8	/ 20
SECTION B	/ 40
SF/UNITS	
TOTAL	/ 80

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

SECTION A (40 marks)

Answer all questions in Section A.

1 A ski jumper lands 96 m from his take off point after taking off at an angle θ to the horizontal as shown in Fig. 1.1 below. The slope is at an angle of 40° and the jumper is in the air for 4.3 s.

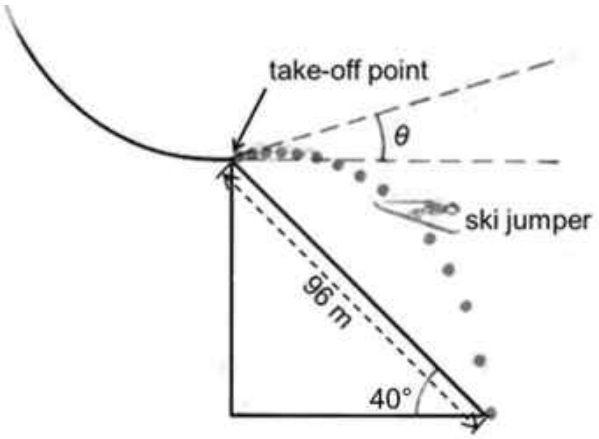


Fig. 1.1

(a) Assuming that air resistance is negligible, determine

(i) the vertical distance from take-off to landing, and,

vertical distance = …… m **[1]**

(ii) the vertical component of the take-off velocity.

velocity = …… m s^{-1} **[2]**

(b) In practice, air resistance is not negligible.

Describe qualitatively the effect of air resistance on the variation, if any, of the component of velocity

(i) in the horizontal direction, and,

……

…… **[1]**

(ii) in the vertical downward direction.

……

……

……

…… **[2]**

2 (a) State the first law of thermodynamics.

.....

..... **[1]**

(b) An ideal gas undergoes a cycle of change, A → B → C → A, as shown in Fig. 2.1.

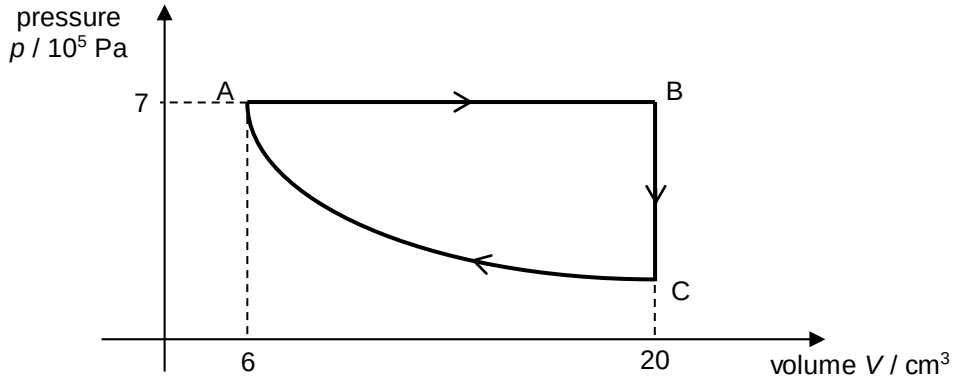


Fig. 2.1

(i) Calculate the work done by the gas during the change A → B.

work done by the gas = …….. J **[2]**

(ii) Fig. 2.2 is a table of energy changes during one complete cycle. Complete Fig. 2.2.

section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A → B			
B → C	-18.0		
C → A	0.00	3.30	

[3]

Fig. 2.2

3 A charged particle of mass m and charge $-q$ is travelling through a vacuum at a constant speed v. It enters a uniform magnetic field of flux density B. The initial angle between the direction of motion of the particle and the direction of the magnetic field is 90° as shown in Fig. 3.1 below.

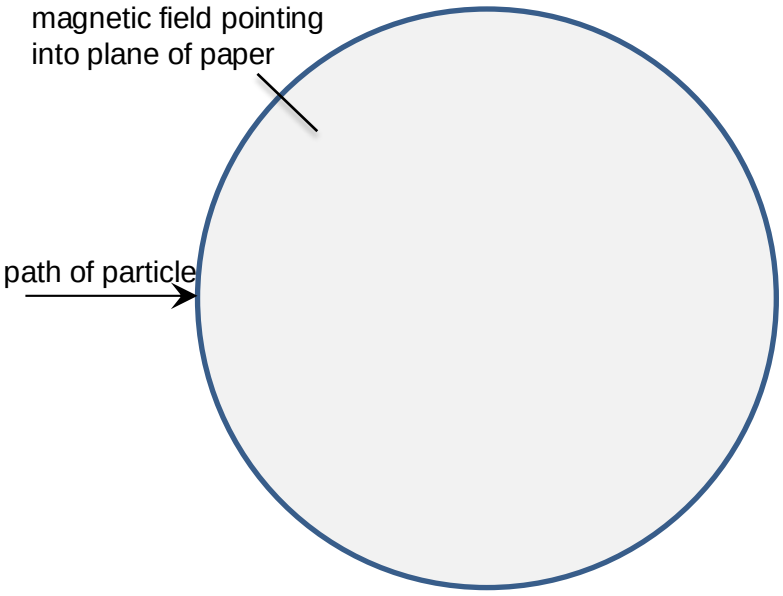


Fig. 3.1

(a) Explain why the path of the particle in the magnetic field is the arc of a circle with a fixed radius.

……

……

……

…… **[3]**

(b) The radius of the arc in **(a)** is r. Show that the specific charge of the particle (which is defined as the ratio $\frac{q}{m}$ of its charge to its mass) is given by the expression

$$\frac{q}{m} = \frac{v}{Br}$$

[1]

(c) Sketch the path of the particle as it enters and subsequently emerges from the field on Fig. 3.1 **[2]**

4 (a) When an electric current is passed through a thin p-type semiconductor slab placed in a uniform magnetic field, a potential difference is set up across the sides of the slab. The voltage measured across both sides is known as the Hall Voltage.

Fig. 4.1 shows a slab with an electric current I passing through it placed perpendicularly to a magnetic field B and the voltmeter measures a Hall Voltage V_H across the sides X and Y.

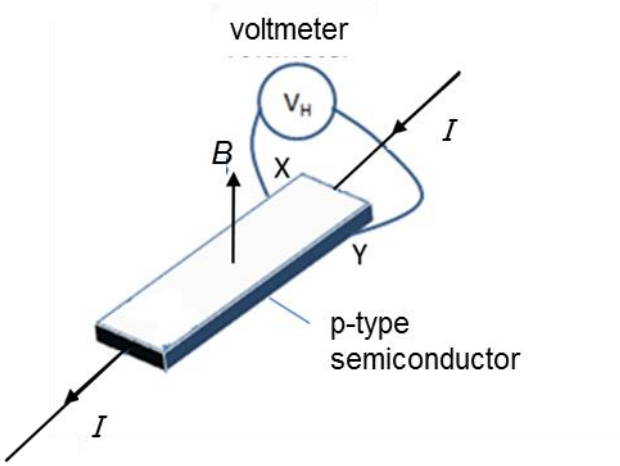


Fig 4.1

(i) Using band theory, explain why a p-type semiconductor has a higher conductivity than an intrinsic semiconductor.

……

……

……

……

……

…… **[3]**

(ii) State which side of the slab, X or Y, is at a higher potential.

…… **[1]**

(iii) Explain the reasoning for your answer in part **(ii).**

……

……

……

…… **[2]**

(b) Describe the formation of the depletion region in a p-n junction.

……

……

……

……

……

……

……

……

……

……

…… **[4]**

(c) State **two** conditions required for the production of a consistent laser beam.

……

……

……

…… **[2]**

5 (a) State **one** similarity and **one** difference between the properties of electric fields and gravitational fields.

similarity:……

……..

difference:……

…….. **[2]**

(b) An oil drop of mass 1.98×10^{-12} g and a charge of -1.12×10^{-18} C is initially at rest between two parallel vertical plates placed 25.0 cm apart. The plates are connected to an electrical source with an e.m.f. of 2.50 kV as shown in Fig. 5.1.

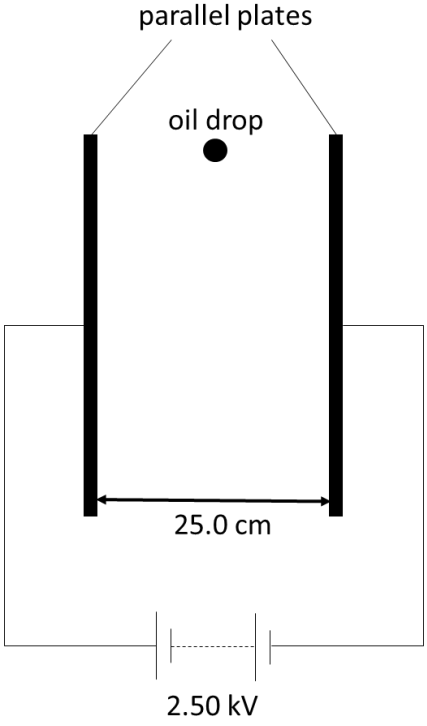


Fig. 5.1

(i) Show that the magnitude of the electric force acting on the oil drop when it is between the plates is 1.12×10^{-14} N.

[2]

(ii) Hence, determine the magnitude and direction of the initial acceleration of the oil drop.

initial acceleration = …… m s^{-2}

direction = …… **[4]**

(iii) State and explain whether the magnitude and direction of the acceleration obtained in part **(ii)** will remain constant throughout the entire motion of the oil drop as it moves between the plates.

……

……

……

…… **[2]**

SECTION B (40 marks)

Answer TWO out of THREE questions in Section B.

6 (a) Give three distinguishing characteristics between the *radioactive decay* and the *fission* of a nucleus.

……

……

……

……

……

……

……

…… **[3]**

(b) Plutonium-239 ($^{239}_{94}Pu$) is the plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors.

(i) Part of the plutonium manufacture process involves the most common isotope of uranium, Uranium-238 ($^{238}_{92}U$) absorbing a neutron. Write a nuclear equation that represents this process.

[1]

(ii) The product formed in the process in **(b)(i)** then quickly undergoes two subsequent beta decays to plutonium. An intermediate radioactive isotope X is formed after the first beta decay.

By considering the nuclear equation for this first beta decay, determine the mass and atomic numbers of X. Show your working clearly.

mass number = ……

atomic number = …… **[4]**

(iii) Hence, write the nuclear equation that represents the second beta decay.

[1]

(iv) A plutonium bomb named “Fat Man” was dropped on Nagasaki on August 9, 1945 ending World War II. At the point of detonation, the following nuclear reaction occurred, incurring a sustained chain reaction process.

$$^{239}_{94}Pu + ^{1}_{0}n \rightarrow ^{100}_{42}Mo + ^{135}_{52}Te + 4^{1}_{0}n$$

Fig. 6.1 lists the binding energy (BE) per nucleon of each of the nuclides in this nuclear reaction.

Nuclide	BE per nucleon / MeV
$^{239}_{94}Pu$	7.56
$^{100}_{42}Mo$	8.61
$^{135}_{52}Te$	8.35

Fig. 6.1

It is estimated that 5.88 kg of plutonium in Fat Man was needed to cause the deadly explosion. Determine the energy released if only 17% of the plutonium undergoes nuclear reaction during the explosion.

energy released = …….. J **[5]**

(c) Plutonium-239 is an alpha emitter with a half-life of 24100 years.

(i) Calculate the amount of time for the number of Plutonium-239 isotopes in a sample to reduce by 30%.

amount of time = ……..…… years **[3]**

(ii) Suggest why plutonium-239 is more dangerous to the body when inhaled as compared to being an external radiation source.

……..

……..

……..

……..

……..

…….. **[3]**

7 **(a)** State what is meant by *simple harmonic motion*.

……

…… **[2]**

(b) Describe how, for a simple harmonic motion, the direction of acceleration varies with the direction of the velocity.

……

……

……

…… **[2]**

(c) A smooth ball of mass *m* is held between two fixed points A and B by means two similar springs, each of spring constant *k*, as shown in Fig. 7.1.

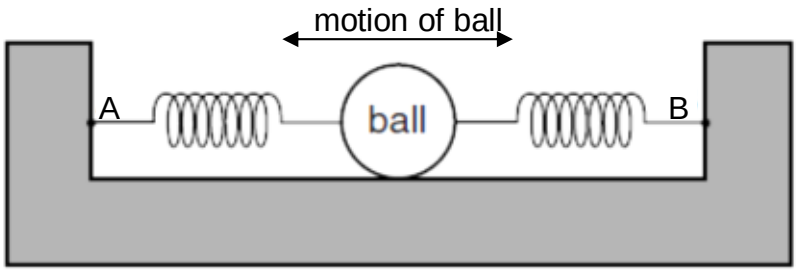


Fig. 7.1

The ball is free to oscillate along the straight line AB on the smooth surface.

When the ball is in equilibrium, the extension of each spring is *e*. The ball 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 ball is given by

$$F = 2kx$$

[2]

(ii) The ball is then released. Show that the acceleration a of the ball is given by

$$a = -\frac{2kx}{m}$$

[2]

(iii) The mass m of the ball is 900 g and the spring constant k is 120 N m^{-1}. By comparing the equations of an object executing simple harmonic motion and that in **(c)(ii)**, determine for the ball,

1. the frequency of oscillation,

frequency = …… Hz **[3]**

2. the amplitude if the maximum acceleration of the ball is 5.2 m s^{-2}, and,

amplitude = …… m **[2]**

3. the maximum kinetic energy of the ball.

maximum kinetic energy = …… J **[2]**

(iv) A student investigates the variation in the kinetic energy, E, of the oscillating ball as shown in Fig. 7.2.

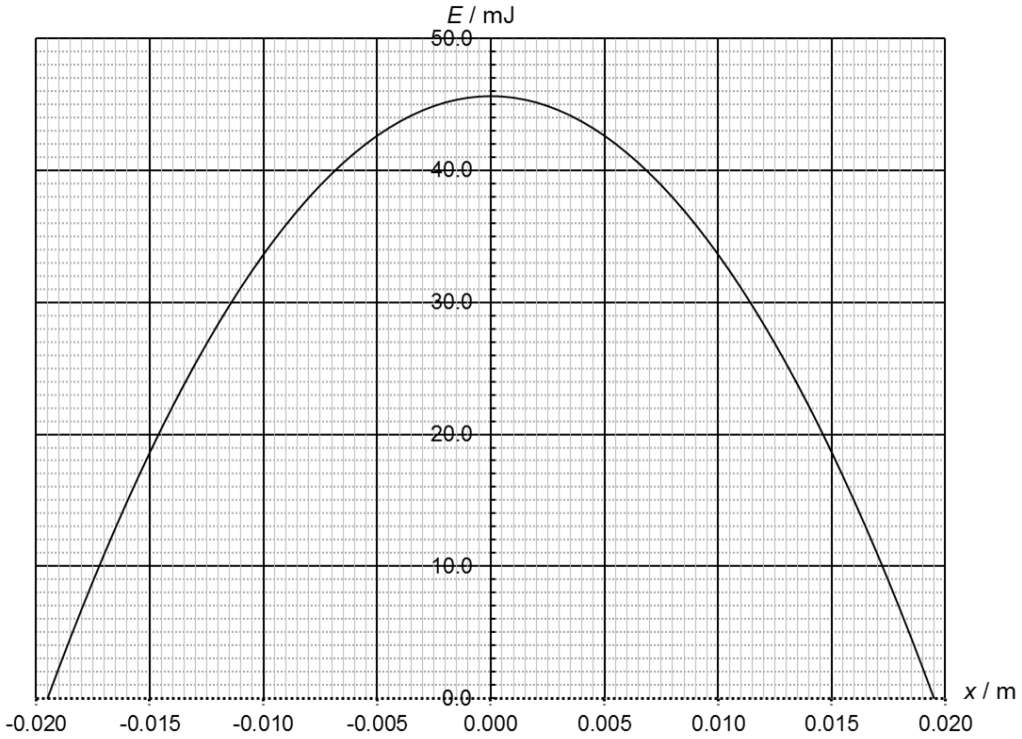


Fig. 7.2

The student repeats the investigation but with a smaller amplitude. The maximum value of E is now found to be 15 mJ.

Use Fig. 7.2 to determine the change in the amplitude. Explain your working.

change in the amplitude = …….. m **[3]**

(d) The experiment was repeated with a rough ball instead. Suggest and explain the effect it would have on the ball's oscillatory motion.

……..

…….. **[2]**

8 **(a)** A rectangular coil is rotating about an axis between two magnets with uniform angular velocity ω due to the action of an external applied force. The uniform magnetic field B between the two magnets is 0.90 T. The coil is rotating at 40 revolutions per second. The number of turns N of the coil is 40. The cross-sectional area A of the coil is 3.0 m^2. A current is found going through the resistor R of resistance 30 Ω. Fig. 8.1 shows the instant when the plane of the coil is in a horizontal position.

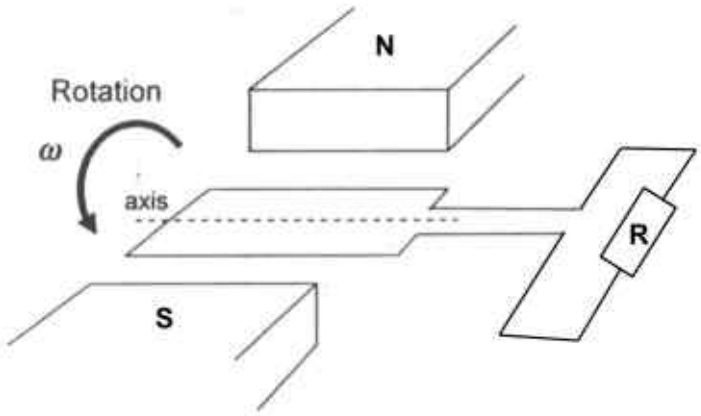


Fig. 8.1

(i) Explain how the current flowing through the resistor R is formed.

……

……

……

…… **[3]**

(ii) On Fig. 8.1, indicate the direction of flow of current and explain your reasoning.

……

……

……

…… **[3]**

(iii) The coil starts rotating when it is in the position shown in Fig. 8.1.

1. Determine the period of the rotation of the coil.

period = …… s **[2]**

2. Determine the maximum current flowing through the coil during the rotation.

maximum current = …… A **[2]**

3. Sketch a graph on Fig. 8.2 showing the variation with time of current through the resistor. Show the values of period and peak current on the graph.



Fig. 8.2

[2]

(iv) Determine the mean power through the resistor R.

mean power = ... W **[3]**

(b) The primary coil of a transformer has 1500 turns and is connected via cables to a 250 $V_{r.m.s.}$ supply. The secondary coil has 50 turns and is connected, through a switch and a diode, to a 10.0 V rechargeable battery, as illustrated in Fig. 8.3.

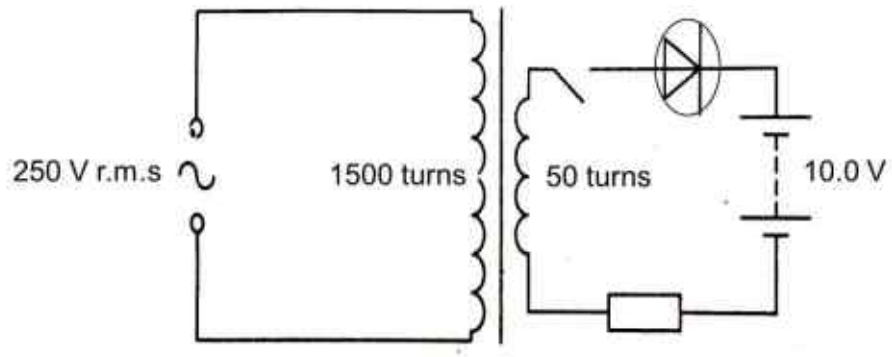


Fig. 8.3

(i) Initially, the switch is open. Considering both the transformer and the diode to be ideal, calculate the r.m.s. potential difference across the secondary coil.

$V_{r.m.s}$ = …… V **[2]**

(ii) The switch is now closed to recharge the battery.

1. Suggest why the diode is necessary in the secondary circuit.

……

……

…… **[2]**

2. Suggest why the resistor is necessary in the secondary circuit.

……

…… **[1]**

NAME: _____ CLASS: _____ INDEX: _____

CATHOLIC JUNIOR COLLEGE
JC2 MID YEAR EXAMINATIONS
Higher 2

PHYSICS [SOLUTIONS]

9646/1

Paper 1

29 AUGUST 2016
1 h 15 mins

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name, tutorial group and index number on this cover page.

Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet),
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

There are a total of **40 Multiple Choice Questions (MCQs)** 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 Answer Sheet (OMR sheet) provided.

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.
Calculators may be used.

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 The Van Der Waal's equation is used to describe the pressure, *P*, volume, *V*, and temperature, *T*, of a real gas,

$$\left(P+\frac{n^2a}{V^2}\right)(V-nb)=nRT$$

where *n* is the number of moles of gas present and *R* is the universal gas constant. *a* and *b* are empirical constants.

What are the units of *a* and *b* respectively?

express derived units as products or quotients of the base units and use the named units listed in 'Summary of Key Quantities, Symbols and Units' as appropriate. **L2**

	Unit of *a*	**Unit of *b***
A	Pa m^6 mol^{-2}	m^3 mol^{-1}
B	mol^2 Pa^{-1} m^{-6}	mol m^{-3}
C	J m^2 mol^{-2}	J m^3 mol^{-1}
D	mol^2 J^{-1} m^{-2}	mol J m^{-3}

Answer: A

As all terms separated with "+" or "-" have the same units,

$$[P]=\left[\frac{n^2a}{V^2}\right]$$

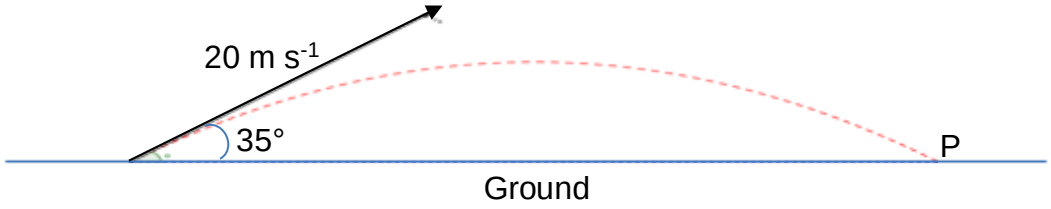
$[a]=$ Pa m^6 mol^{-2}

$[V]=[nb]$

$[b]=$ m^3 mol^{-1}

2 A student throws a stone 35° above the ground at an initial speed of 20 m s^{-1}. It travels in a projectile motion until it hits the ground at P with the same speed.

add and subtract coplanar vectors. L2



What is the magnitude of the change in velocity of the stone just before hitting the ground at P?

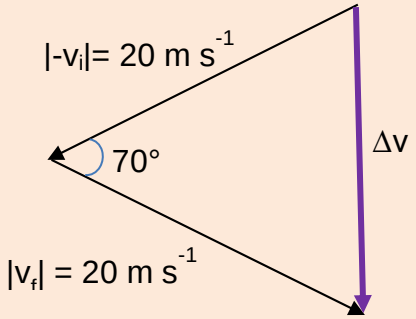
A 0.0 m s^{-1} **B** 20 m s^{-1} **C** 23 m s^{-1} **D** 33 m s^{-1}

Answer: C

Change in velocity,

$\Delta v = v_f - v_i$

$\Delta v = v_f + (-v_i)$

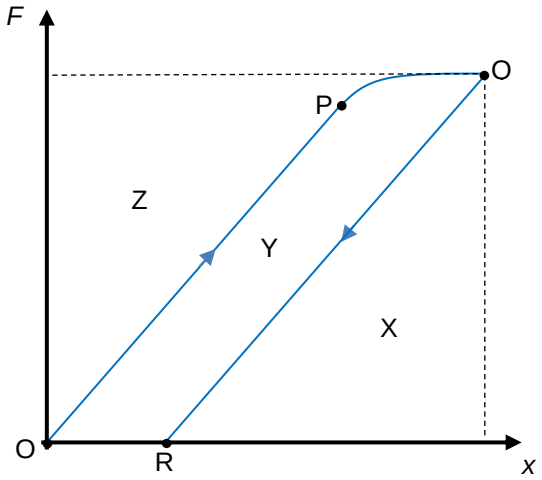


$\Delta v = \sqrt{(20)^2 + (20)^2 - 2(20)(20)\cos 70°}$

$\Delta v = 23 \text{ m s}^{-1}$

3 A metal wire is stretched by a varying force *F*, causing its extension *x* to increase as shown by the line OPQ on the graph. The force is then gradually reduced to zero and the relation between the force and extension is indicated by line QR.

deduce the elastic potential energy in a deformed material from the area under the force extension graph. L2



Which area represents the elastic potential energy stored in the wire at Q?

A X **B** Y **C** Z **D** X + Y

Answer: D

The total elastic potential energy stored at Q before decreasing the force *F* is the total area under the graph X+Y.

Area X is the recoverable energy from the spring.

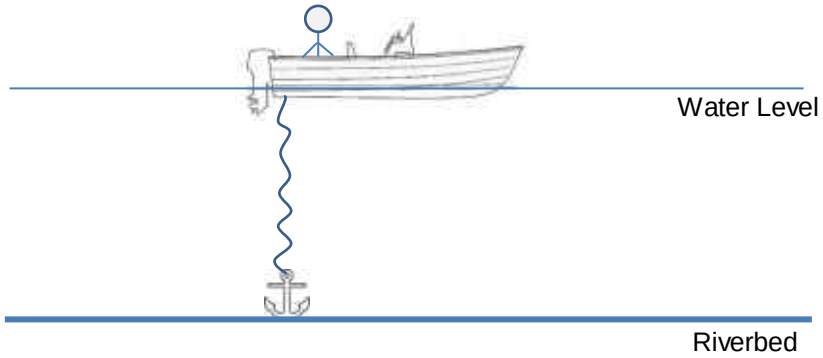
Area Y is the net work done on the spring when the extension returns to point R.

Area Z has no meaning currently.

4 The anchor of a small boat is initially completely submerged in water and resting on the riverbed.

recall and apply the principle that, for an object floating in equilibrium, the upthrust is equal to the weight of the object to new L3

situations or to solve related problems.



What happens to the water level with respect to the boat when the fisherman first pulls the anchor up and when the anchor is finally on the small boat? Assume that the rope tied to the anchor is of negligible mass and volume.

A The water level decreases when the fisherman first pulls the anchor up and then increases when the anchor is finally on the small boat.

B The water level increases when the fisherman first pulls the anchor up and then decreases when the anchor is finally on the small boat.

C The water level increases when the fisherman first pulls the anchor up and then increases further when the anchor is finally on the small boat.

D The water level decreases when the fisherman first pulls the anchor up and then decreases further when the anchor is finally on the small boat.

Answer: C

The water level with respect to the boat indicates the upthrust on the boat. When the water level is high, the upthrust on the boat is high and vice versa (Archimedes' Principle).

When the anchor is resting on the riverbed, the rope is not taut. Hence, the upthrust on the boat only supports the boat and the fisherman.

When the fisherman is pulling the anchor up at a constant speed, the force on the boat by the rope, which is numerically equal to the tension of the rope, *T*, acts downwards. As the new upthrust on the boat takes into account the additional force so that the boat can remain afloat, the boat will displace more fluid, hence water level increases.

By Newton 2nd law, taking upward as positive, during the ascending of the anchor, the resultant force on the anchor, (U – upthrust, W – weight of anchor)

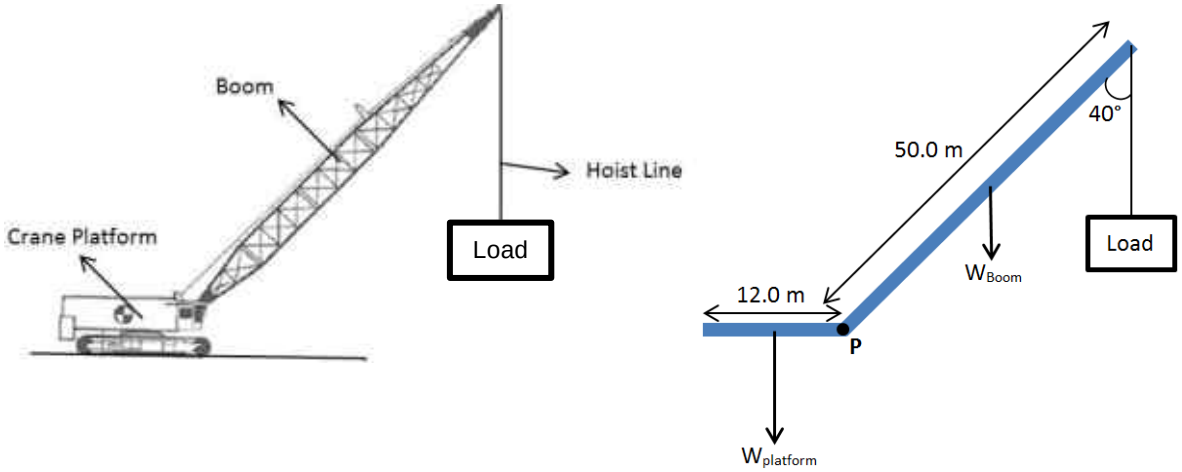
$$\sum F = U + T - W = 0$$

$$T = W - U \text{ -(1)}$$

When the anchor is out of the water and on the boat, the new upthrust on the boat takes into account the additional full weight of the anchor. Therefore, comparing with equation 1, where T, which is less than W, is the additional force on the boat. Therefore, the new water level will increase further as it takes into account a larger magnitude of the weight of the anchor.

5 A crane starts to lift a load of 5.80 × 104 kg load from the ground.

apply the principle of moments to new situations or to solve related problems L2



The diagram on the right is a simplified schematic representation of the crane and load on the left.

If the platform has a uniform mass of 4.00×10^5 kg and the boom has a uniform mass of 4.00×10^4 kg what is the maximum mass that the crane can lift vertically at constant speed at the end of the boom without the crane toppling over at point P?

A 2.80×10^4 kg **B** 4.27×10^4 kg **C** 4.40×10^4 kg **D** 5.47×10^4 kg

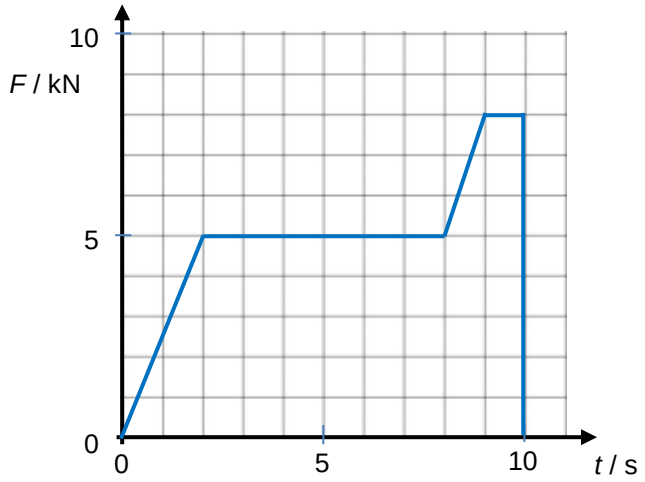
Answer: D

Maximum weight before toppling over is when the force acting on the crane by the ground is solely acting at point P.

By principle of moments and taking turning point at P,
Clockwise moment = Anticlockwise moment
$4.00\times10^4\times25.0\sin 40°\times \cancel{9.81} + M_{load}\times50.0\sin 40°\times\cancel{9.81} = 4.00\times10^5\times6\times\cancel{9.81}$
$M_{load} = 5.467\times10^4 =$ **5.47×10^4 kg**

6 The following graph describes the variation of the resultant force *F* on an object of mass 2500 kg with time *t* until 10 s.

define linear momentum and impulse L2



If the object is initially at rest when *t* = 0 s, what is the object's speed at *t* = 8 s?

A 14 m s^{-1} **B** 16 m s^{-1} **C** 18 m s^{-1} **D** 20 m s^{-1}

Answer: A
The area under a F-t graph gives the impulse of the object. Since the value of the impulse is numerically equal to the change in momentum of the object, at t = 8 s,

$\Delta p = p_f - p_i$

$p_f - 0 = \Delta p$

$$v_f = \frac{\frac{1}{2}(2)(5\times10^3)+(6)(5\times10^3)}{2500}$$

$v_f = 14$ m s^{-1}

7 An object falls freely from rest vertically to the ground. The effects of air resistance on the object are negligible.

The object travels 60 % of the total vertical distance to the ground in the last second of its fall.

What is the total vertical distance?

A 1.8 m **B** 2.1 m **C** 36 m **D** 71 m

solve problems using equations which represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance. L3

Answer: C

Let the total distance be *d*
Taking downward as positive, for the last second of the motion,

$$s = ut + \frac{1}{2}at^2$$

$$0.6d = v(1) + \frac{1}{2}a(1)^2$$

A change to symbol v as the velocity at the start of the second part of the motion is the final velocity v of the first part of the motion.

$$v = 0.6d - \frac{1}{2}a \text{ --(1)}$$

For the first part of the motion,

$v^2 = u^2 + 2as$

$v^2 = 0 + 2a(0.4d)$

$v^2 = 0 + 0.8ad$ --(2)

Substitute (1) in (2),

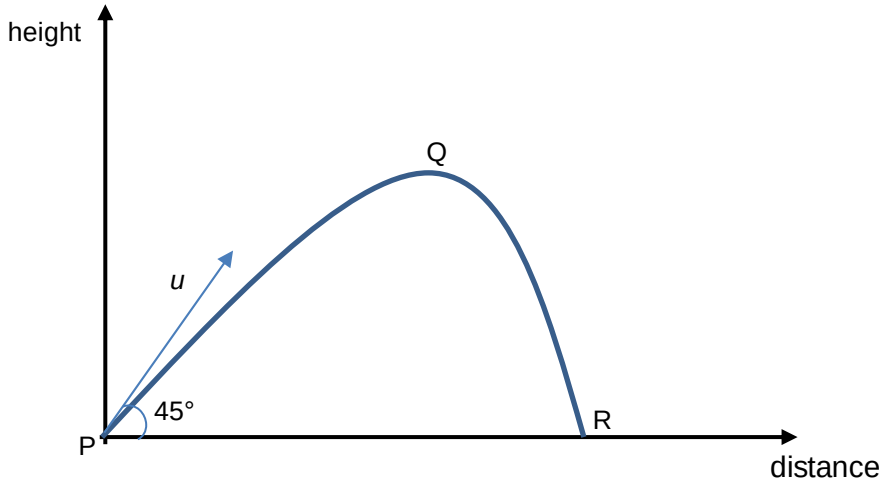
$$0.36d^2 + \frac{1}{4}a^2 - 1.4ad = 0$$

$$d = \frac{-(-1.4a) \pm \sqrt{(-1.4a)^2 - 4(0.36)\left(\frac{1}{4}a^2\right)}}{2(0.36)}$$

$d = 36.3\,\text{m}$. (Reject $d = 1.84\,\text{m}$, as the time taken for the total distance of 1.84 m is only 0.61 s, did not meet the description of the question, 60 % of the total distance in the last second.)

8 An object is projected with a certain speed *u* at an angle of 45° to the horizontal from the ground at point P. It travels through air with significant drag force on it, reaches the maximum height at Q, falls and hits the ground at a certain distance away at R.

describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance. L2



Which of the following statement is true?

A The time taken for the object to travel from P to Q is more than the time taken for it to travel from Q to R.

B The time taken for the object to travel from P to Q is less than the time taken for it to travel from Q to R.

C The time taken for the object to travel from P to Q is the same as the time taken for it to travel from Q to R.

D The time taken for the object to travel from P to Q can be the same as or more or less than the time taken for it to travel from Q to R, depending on speed *u*.

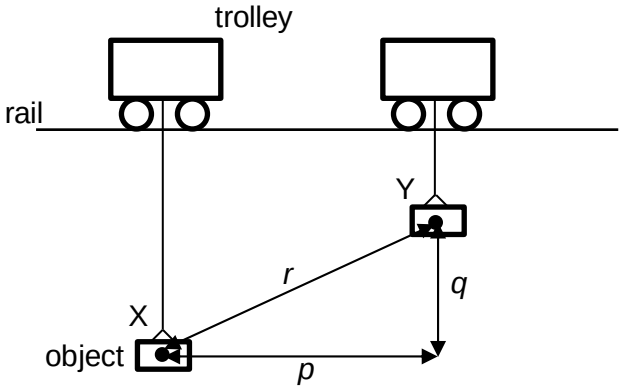
Answer: B

The object moves through with a drag force in both vertical and horizontal direction.

In the horizontal direction, the horizontal velocity will reduce to zero, thus showing the shorter range from Q to R, giving the false impression that the time taken is shorter.

However, when considering the vertical direction, the vertical speed when travelling from P to Q is higher than the vertical speed when travelling from Q to R. Since the vertical distance is the same from P to Q and from Q to R, with larger speed when traveling from P to Q, the time taken for the object to travel from P to Q is lower than the time taken from Q to R.

9 An object of weight *W* hangs from a trolley that runs along a rail. The trolley moves horizontally through a distance *p* and simultaneously raises the object through a height *q*.



As a result, the object moves through a distance *r* from X to Y. It starts and finishes at rest.

Which of the following statements about the object during this process **must** be correct?

A The work done on the object is *Wr*.

B The net work done on the object is 0.

show an understanding of the concept of work in terms of the product of a force and displacement in the direction of the force. L3

C The gravitational potential energy at Y is *Wq*.

D The increase in kinetic energy of the weight is *W(p + q)*.

Answer: B

By the work-energy theorem the net work done is equals to the change in the kinetic energy of the object.

Since the object starts and ends at rest the change in kinetic energy is zero.

10 The data below are taken from a test of a petrol engine for a motor car.

show an appreciation for the implications of energy losses in practical devices and use the concept of efficiency to solve problems. **L2**

power output	150 kW
fuel consumption	20 litres per hour
energy content of fuel	40 MJ per litre

Which expression will evaluate the efficiency of the engine?

A $\dfrac{150 \times 10^3}{40 \times 10^6 \times 20 \times 60 \times 60}$

B $\dfrac{150 \times 10^3 \times 60 \times 60}{20 \times 40 \times 10^6}$

C $\dfrac{150 \times 10^3 \times 40 \times 10^6 \times 20}{60 \times 60}$

D $\dfrac{150 \times 10^3 \times 20}{40 \times 10^3 \times 60 \times 60}$

Answer: B

$$\text{Efficiency} = \frac{P_{output}}{P_{input}} = \frac{150 \times 10^3 \text{ J s}^{-1}}{20 \text{ litres per hour} \times 40 \times 10^6 \text{ J per litre}} = \frac{150 \times 10^3 \times 60 \times 60}{20 \times 40 \times 10^6}$$

11 Two toy cars are set to run round a circular track of radius 80 m. Each of them moves at a constant speed. At time *t*, car A overtakes car B. 4 minutes later, car A passes B again for the second time.

What is the period of car A, if the period of car B was 60 seconds?

A 15 s **B** 48 s **C** 120 s **D** 240 s

understand and use the concept of angular velocity to solve problems. L3

Answer: B

When car A overtakes car B again, it must have travelled an additional lap as compared to the number of laps car B has travelled in the next 4 minutes.

Therefore, $\theta_A - \theta_B = 2\pi$

$$\frac{2\pi}{T_A}(240) - \frac{2\pi}{(60)}(240) = 2\pi$$

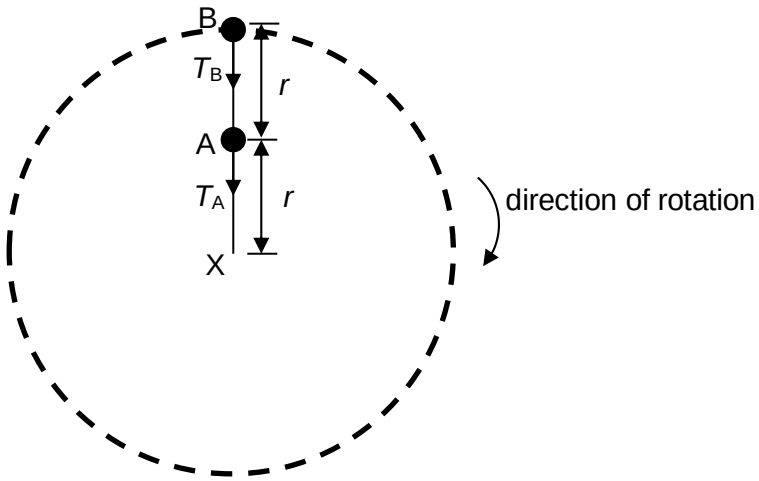
$$\frac{240}{T_A} - 4 = 1$$

$$T_A = \frac{240}{5}$$

$$= 48 \text{ s}$$

12 Two spheres A and B of equal mass, *m*, are attached on a string which moves in a vertical circular motion. A is at a distance *r* while B is 2*r* away from the end of the string X as shown in the figure below.

recall and use centripetal force F = mrω2, F = mv2/r to solve problems. **L3**



The tensions in each part of the strings are T_A and T_B respectively.

Which of the following statements about the forces acting on objects A and B are correct?

A The magnitude of T_A and T_B are always constant.

B Throughout the motion, the net force acting on sphere A is only T_A.

C For the objects to execute circular motion T_B can have a magnitude of zero.

D The magnitude of T_A and T_B are always equal as they are action reaction forces.

Answer: C

Option A: Since it is a vertical circular motion, the magnitude of the tension T_A and T_B cannot be constant throughout.

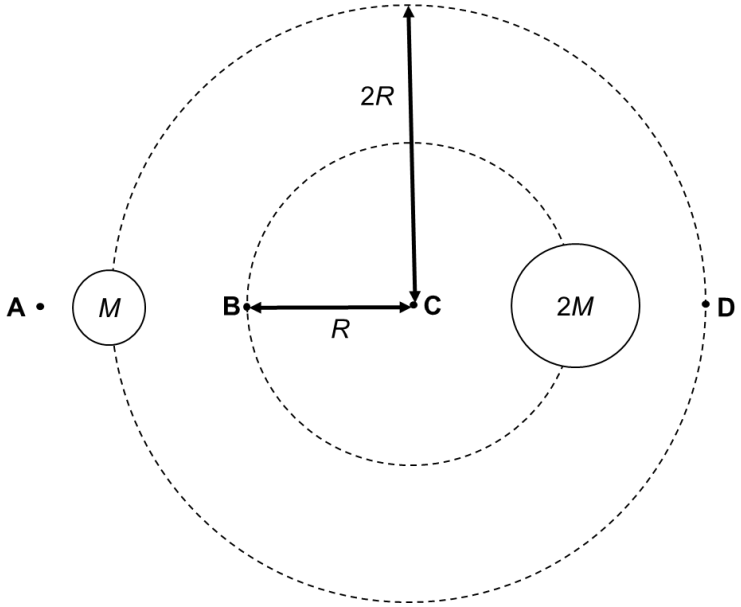
Option B: Sphere A will experience three forces acting on it all the time. T_A, T_B and its own weight mg.

Option C: This is true only when sphere B is at its maximum height with the minimum speed passing through that point such that its own weight is the only force necessary to contribute to the centripetal force.

Option D: T_A and T_B are not action reaction pair forces as these two forces exists on different segment of the strings. And their magnitudes can be only equal when the centripetal force acting on A is its own weight.

13 Two binary stars of masses *M* and 2*M* revolve about their common centre of mass in orbits of radius 2*R* and *R* respectively.

recall and apply the equation g = GM/r^2 for the gravitational field strength of a point mass to new situations or to solve related problems L2



At which point does the gravitational field strength have the lowest magnitude?

Answer: B

The point of the lowest magnitude of the field strength is at the neutral point, which should be between the two masses, where the forces due to the two stars can cancel out.

The neutral point is expected to be closer to the smaller mass, since the force due to two masses needs to be equal in magnitude and opposite in direction.

14 On October 19 2016, the spacecraft *Juno* will enter into a circular polar orbit with a period of 14 days around the planet Jupiter which has a mass of 1.90×10^{27} kg.

What is the radius of *Juno's* orbit?

analyse circular orbits in inverse square law fields by relating the gravitational force to the centripetal accelerations it causes — L2

A 8.64×10^{4} m **B** 1.67×10^{9} m **C** 6.29×10^{17} m **D** 4.69×10^{27} m

Answer: B

Since the gravitational force of Jupiter provides for the centripetal force:

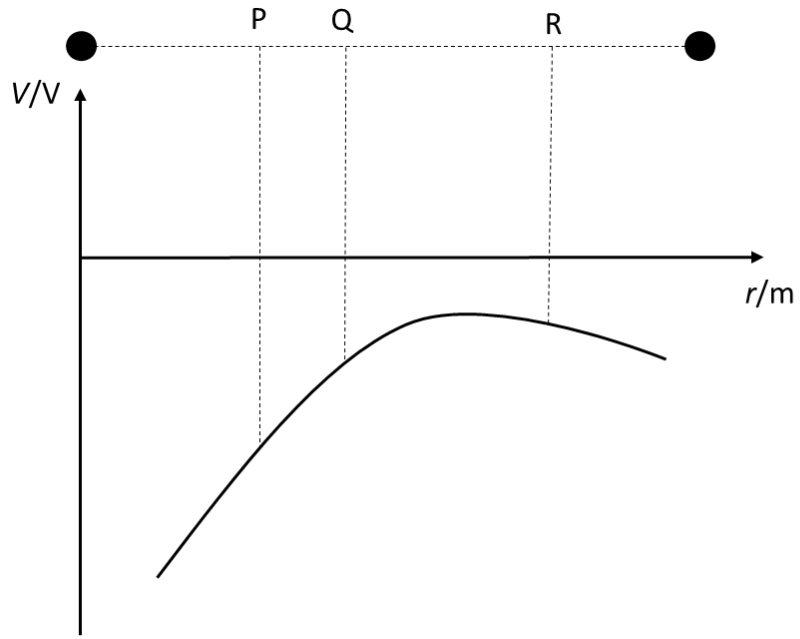
$$\frac{GMm}{r^2} = mr\omega^2$$

$$r^3 = \frac{GM}{\omega^2} = \frac{GMT^2}{4\pi^2}$$

$$r = \sqrt[3]{\frac{(6.67\times10^{-11})(1.90\times10^{27})(14\times24\times3600)^2}{4\pi^2}} = 1.67\times10^{9}\ \text{m}$$

15 Two charges are placed in free space. The variation of the electric potential *V,* with the distance *r* from the left charge along the line joining the centres of the charges is shown below.

define potential at a point in terms of the work done in bringing unit positive charge from infinity to the point. — L3



Which of the following statements is true?

A Any charge placed at point P will experience a resultant force towards the left.

B The electric field strength at point Q is larger than the electric field strength at P.

C Net positive work needs to be done by an external agent to move a negative charge from point R to point P.

D A positive charge at P has more electric potential energy as compared to an identical positive charge placed at R.

Answer: C

Option A: Depending on the charge of the object, the force could either be left (positive charge) or right (negative charge).

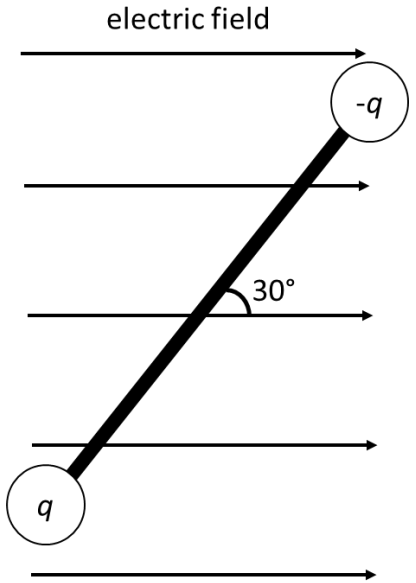
Option B: The magnitude of the field strength can be found using $E = -\frac{dV}{dr}$. The gradient at P is larger than Q, so the field strength is larger at P

Option C: The potential at P is lower than R, and thus ΔV is a negative number. The work done is $W = q\Delta V$ and this is a positive number since q is also negative. So, the work done is positive

Option D: The potential energy is given by $U = qV$, and so, since V is more negative at P than at R, the potential energy is lower at P than at R.

16 Two charges of electric charge q and $-q$ connected by a light electrically insulated rigid rod of length L are placed in a uniform electric field of electric field strength E as shown in the figure.

calculate the forces on charges in uniform electric fields. L2



Which of the following is the correct expression for the torque due to the couple?

A $\frac{qEL}{2}$

B qEL

C $2qEL$

D q^2E^2L

Answer: A

The torque due to a couple is found by:

$$\begin{aligned}\tau &= \text{force of the couple} \times \text{perpendicular distance between the couple} \\ &= q \times E \times L \sin 30 \\ &= \frac{qEL}{2}\end{aligned}$$

17 An object moving in simple harmonic motion has a maximum velocity v_0 and an amplitude x_0.

What is its velocity, in terms of v_0, when it is at a distance $0.25x_0$ from its amplitude position?

recognise and use v = v0cosωt, v = ±√(x0^2 - x^2) L2

A $0.13v_0$

B $0.25v_0$

C $0.66v_0$

D $0.75v_0$

Answer: C

$$\begin{aligned}v &= \pm\omega\sqrt{x_0^2 - x^2} \\ &= \pm\omega\sqrt{x_0^2 - (0.75x_0)^2} \\ &= \pm\omega\sqrt{(1-0.75^2)x_0^2} \\ &= \pm 0.66\omega x_0 \\ &= 0.66v_0\end{aligned}$$

18 Some doors use a spring system to ensure the door closes again after it is opened. These springs are usually damped.

describe the practical examples of damped oscillations with particular reference to L1

If the spring used causes critical damping in the door, which of the following will happen when the door is opened?

the effects of the degree of damping and the importance of critical damping in cases such as a car suspension system

A The door will quickly swing shut without oscillating.

B The door will continue to swing back and forth for a long time.

C The door will take a long time to swing shut without oscillating.

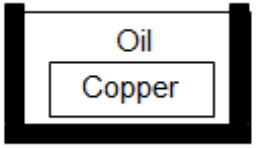
D The door will swing back and forth, but will come to a stop eventually.

Answer: A

Critical damping is defined as damped system where the object returns to equilibrium as quickly as possible. This matches the description in option A

19 A copper block at 500 °C is cooled in an oil bath that was initially at 20 °C.

Heat capacity **L2**



Using the ratios below, calculate the temperature at thermal equilibrium. Assume no heat transfer with the surroundings and the container.

$$\frac{\text{density of oil}}{\text{density of copper}} = 0.110$$

$$\frac{\text{specific heat capacity of oil}}{\text{specific heat capacity of copper}} = 4.29$$

$$\frac{\text{volume of oil bath}}{\text{volume of copper}} = 10.0$$

A 41.6 °C **B** 104 °C **C** 160 °C **D** 416 °C

Answer: B

Heat gain by oil = heat loss by copper

$m_o c_o \Delta T_o = m_c c_c \Delta T_c$

$V_o \rho_o c_o (T - 20) = V_c \rho_c c_c (500 - T)$

$$\frac{V_o}{V_c}\frac{\rho_o}{\rho_c}\frac{c_o}{c_c} = \frac{(500 - T)}{(T - 20)}$$

$$10 \text{ x } 0.110 \text{ x } 4.29 = \frac{(500 - T)}{(T - 20)}$$

$T = 104^{\circ}C$

20 The temperature of an ideal gas is raised from 32.1 ºC to 40.5 ºC. What is the percentage increase in the r.m.s. speed of its gas particles? **Kinetic theory** **L2**

A 1.4% **B** 2.8% **C** 12% **D** 13%

Answer: A

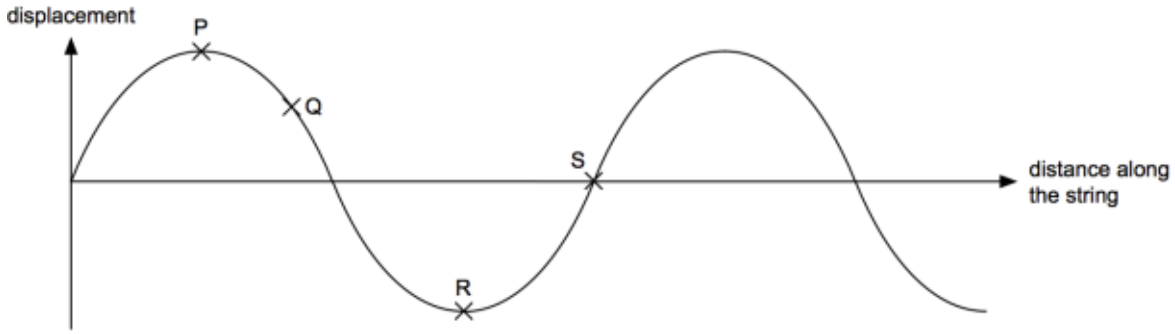
$C_{rms} \propto \sqrt{T}$

$$\frac{C_{rms,2}}{C_{rms,1}} = \sqrt{\frac{40.5 + 273.15}{32.1 + 273.15}}$$

$C_{rms,2} = 1.014\, C_{rms,1}$

C_{rms} has increased by 1.4%

21 The figure shows the shape at a particular instant of part of a transverse wave travelling from left to right along a string. **Graphing disp - dist** **L2**



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.

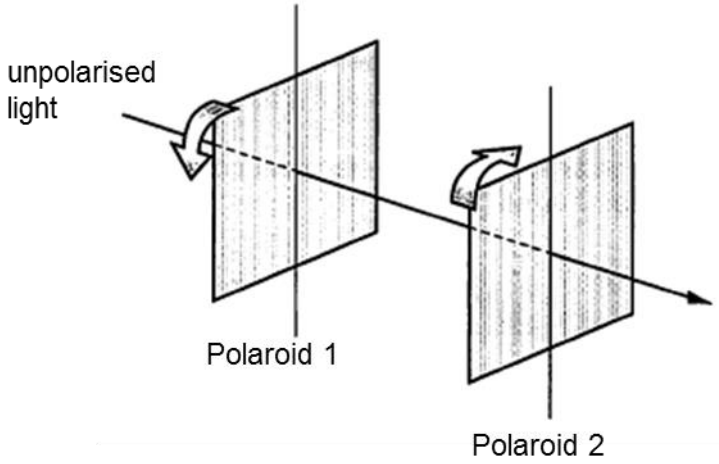
C The energy of P and S is entirely kinetic.

D The acceleration of P and R is a maximum.

Answer: D

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.

22 The diagram shows a beam of initially unpolarised light passing through two Polaroid filters. **polarisation** **L2**



The transmitting axes of these filters are initially aligned. The two filters are now rotated through 360° in opposite directions in their own plane at equal speeds.

How many maxima of intensity occur in the light emerging from the Polaroid on the right?

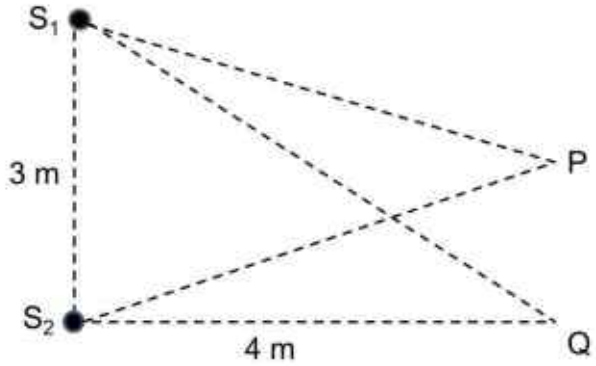
A 2 **B** 3 **C** 5 **D** 9

Answer: C

Maxima will be obtained when the filters are aligned parallel to each other.
In a rotation of 360°, that occurs a total of 5 times (including at the start).

23 Two sources of waves, S_1 and S_2, are situated as shown in the figure below. Individually, each source emits waves of intensity *I*.

Two source interference **L1**



Equidistant from S_1 and S_2, a detector at P registers a steady minimum wave intensity. The same detector registers the next steady minimum intensity when it moves to point Q. Which of the following statements is false about the two sources of waves?

A The two sources of waves are coherent.

B The two sources of waves have the same amplitude.

C The two sources of waves have a similar wavelength of 2 m.

D The two sources of waves have a phase difference of π radians.

Answer: C

To obtain a steady interference with minimum intensity at point P, both the sources must be coherent and be out of phase by π radians. Both sources can be of the same amplitude. The next minimum produced at Q corresponds to a path difference of 1 m and this should be equal to one wavelength. Thus, the wavelength of the waves must be 1 m and not 2 m.

24 Monochromatic light is incident normally on a diffraction grating and first order diffraction is observed at an angle of 28.6°.

Diffraction grating **L2**

Which of the following statements about the diffraction pattern produced by the grating is true?

A The second order image is observed at 57.2° and there is a total of 3 intensity maxima formed on the screen.

B The second order image is observed at 57.2° and there is a total of 5 intensity maxima formed on the screen.

C The second order image is observed at 73.2° and there is a total of 5 intensity maxima formed on the screen.

D The second order image is observed at 73.2° and there is a total of 7 intensity maxima formed on the screen.

Answer: C

Using $d\sin\theta = n\lambda$

$$\frac{d}{\lambda} = \frac{n}{\sin\theta} = \frac{1}{\sin 28.6}$$

For 2nd order image,

$$\frac{d}{\lambda} = \frac{1}{\sin 28.6} = \frac{2}{\sin\theta_2}$$

$$\theta_2 = 73.2°$$

Highest order max visible is determined from largest angle of diffraction possible where $\theta = 90°$

$$\frac{d}{\lambda} = \frac{1}{\sin 28.6} = \frac{n}{\sin 90}$$

$n = 2.089 = 2$ (2 max on each side of the central max, total max = 2+2+1 = 5)

25 The potential difference across an electrical component is 20 V. The time taken for charge carriers to move through this component is 15 s, and, in this time, the energy of the charge carriers changes by 12 J.

recall and solve problems using V = W/Q. L2

What is the electrical resistance of this component?

A 0.040 Ω **B** 0.80 Ω **C** 33 Ω **D** 500 Ω

Answer: D

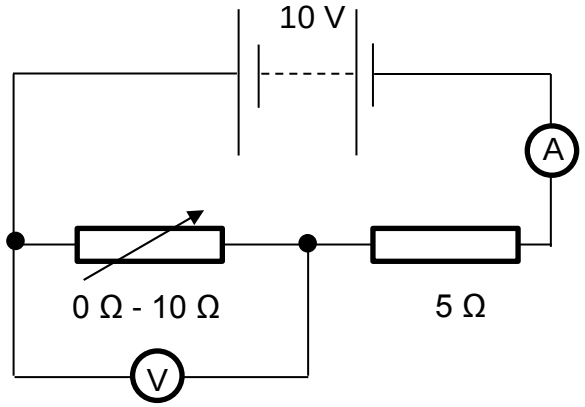
Charge flowing through component = $\frac{W}{V} = \frac{12}{20} = 0.600$ C

Current flowing through = $\frac{Q}{t} = \frac{0.600}{15} = 0.04$ A

Resistance of the component = $\frac{V}{I} = \frac{20}{0.04} = 500\ \Omega$

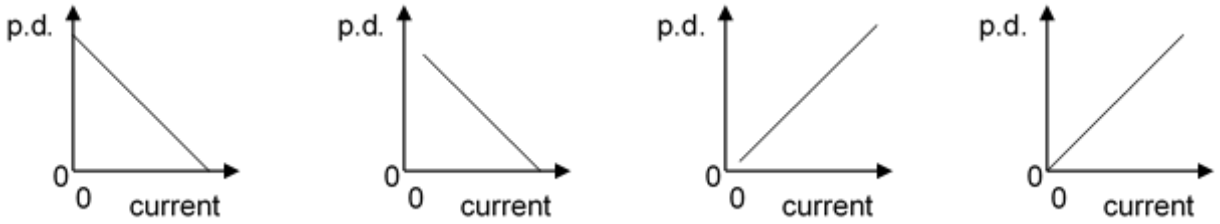
26 A 10 V battery is in series with an ammeter, a 5 Ω fixed resistor and a 0 - 10 Ω variable resistor. A high-resistance voltmeter is connected across the variable resistor.

Show an understanding of the use of a potential divider circuit as a source of variable p.d. L3



The resistance of the variable resistor is changed from zero to its maximum value.

Which graph shows how the potential difference (p.d.) measured by the voltmeter varies with the current measured by the ammeter?



A **B** **C** **D**

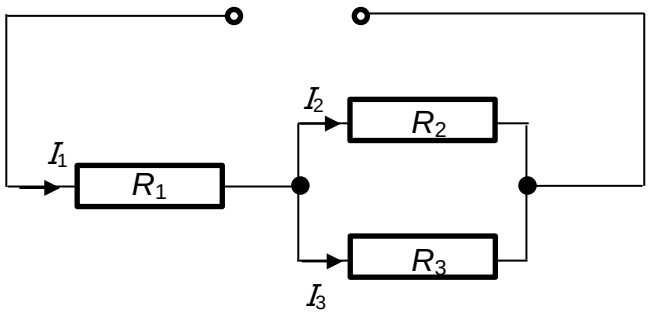
Answer: B

When the resistance of the variable resistor is set to its minimum (0 Ω) the p.d. is zero. But that is when the current in the entire circuit is its maximum.

On the other hand when the resistance of the variable resistor is at its maximum (10 Ω) the p.d is non-zero while the current is a non-zero minimum and therefore, the graph should not touch the y-axis.

27 The circuit diagram shows three fixed resistors R_1, R_2 and R_3 connected to a power supply. The currents flowing through each of these resistors are I_1, I_2 and I_3 respectively.

solve problems involving series and parallel circuits for one source of e.m.f. L2



Which of the following expression represents the ratio of $\frac{R_2}{R_3}$?

A $\frac{I_2}{I_3}$

B $\frac{I_1}{I_3} - 1$

C $\frac{I_1}{I_2} - 1$

D $1 + \frac{I_3}{I_2}$

Answer: C

Since R_2 and R_3 are in parallel, the potential difference is equal across both of them.

So, $I_2R_2 = I_3R_3$,

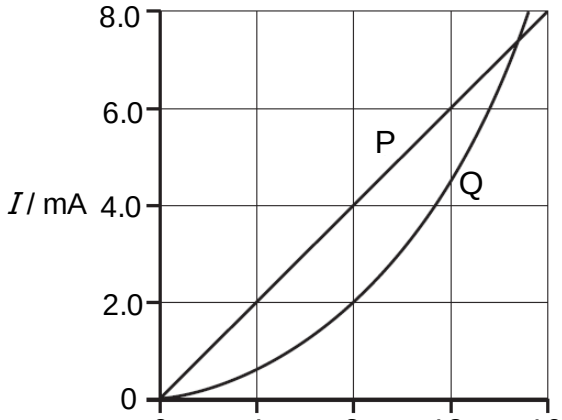
$$\frac{R_2}{R_3} = \frac{I_3}{I_2}$$

$$= \frac{I_1 - I_2}{I_2}$$

$$= \frac{I_1}{I_2} - 1$$

28 The *I*-V characteristics of two electrical components P and Q are shown below.

sketch and explain the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp. L3



Which statement is correct?

A P is a resistor and Q is a filament lamp.

B The ratio $\frac{\text{resistance of P}}{\text{resistance of Q}}$ is always less than 1.

C At 2.0 mA the power dissipated through Q is always twice that of P.

D At the point where the two lines intersect the resistance of Q is approximately twice that of P.

Answer: D

Option A: P is an ohmic conductor (resistor) while Q is a semiconductor.

Option B: Resistance of P is always smaller than the resistance of Q for values of V to the left of the intersection point. At the intersection point the resistance are equal. While to the right the resistance of P is larger than the resistance of Q.

Option C: The power dissipated in the resistors at 2.0 mA is proportional to $\frac{V^2}{R}$ or $(I^2 R)$.

$$\text{So } \frac{\text{Power dissipated through P}}{\text{Power dissipated through Q}} = \frac{V_P^{\,2}}{R_P} \div \frac{V_Q^{\,2}}{R_Q}$$

$$= \frac{V_P^{\,2}}{V_Q^{\,2}} \times \frac{R_Q}{R_P}$$

$$= \left(\frac{4}{8}\right)^2 \times \frac{\frac{8}{2x10^{-3}}}{\frac{4}{2x10^{-3}}}$$

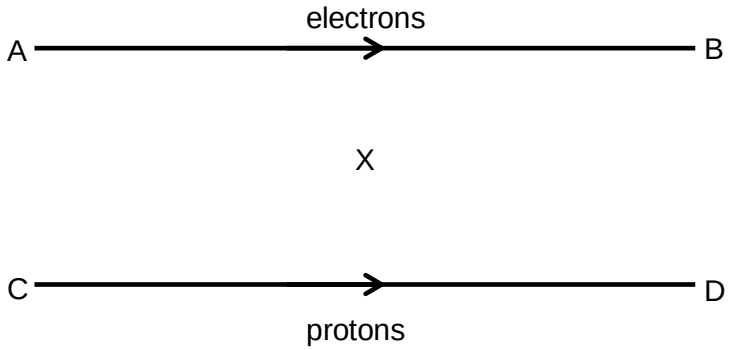
$$= \frac{1}{2}$$

$\therefore$ Power dissipated through Q is twice the power dissipated through P.

Option D:At the point of intersection the resistance of P and Q are equal

29 A beam of electrons in AB and another made out of protons in CD are parallel to each other.

show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field. L1



The rate of proton flow in CD is twice that of the electrons in AB. What direction is the magnetic field at point X, which is equidistant from AB and CD?

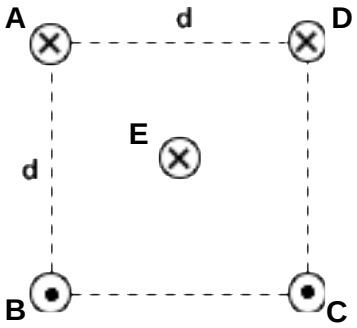
A Towards AB **B** Towards CD **C** Into the page **D** Out of the page

Answer: D

The current is flowing from B to A and C to D and using the Right Hand Grip Rule, the magnetic field at X is pointing outwards from the paper.

30 Five straight and parallel wires are arranged as shown in the diagram below, and each carries a steady current *I*.

show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field. L2



Which of the following statements incorrectly describes the above scenario?

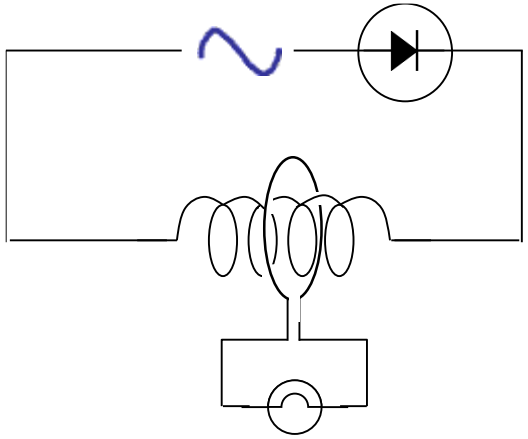
A The resultant force on wire E due to wires A, B, C and D is pointing towards line AD, perpendicular to AD.
B The resultant force on wire E due to wires B and C is pointing towards line AD, perpendicular to AD.
C The resultant force on wire E due to wires A and D is pointing towards line AD, perpendicular to AD.
D The resultant force on wire E due to wires B and D is pointing towards line AD, perpendicular to AD.

Answer: D

Using FLHR, all scenarios from options A to C are correct, while option D is incorrect.

31 A circuit containing a circular loop of wire connected to a low power light bulb is positioned around a solenoid connected to a sinusoidal AC source and a diode as shown in the diagram below.

explain simple applications of electromagnetic induction. L2



Which of the following statements is true?

A The light bulb lights up because the magnetic flux linkage through the loop varies with time.

B The light bulb lights up because the magnetic flux linkage through the loop reverses its direction every cycle.

C The light bulb does not light up because the magnetic flux linkage through the loop does not reverse its direction.

D The light bulb does not light up because the diode prevents current from flowing and thus producing any magnetic flux in the solenoid.

Answer: A

With a variation of the current, there is a variation of magnetic flux density, and thus magnetic flux linkage. An e.m.f. will be induced in the secondary circuit, causing the bulb to be lit.

32 Two coils are linked by a soft iron bar as shown in Fig. A. A current source is connected to the primary coil. The primary current *Ip* varies with time as shown by the Fig. B.

show an understanding of the principle of operation of a simple iron-cored transformer and recall and solve problems using Ns /Np = Vs /Vp = L2

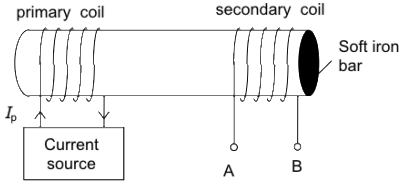


Fig. A

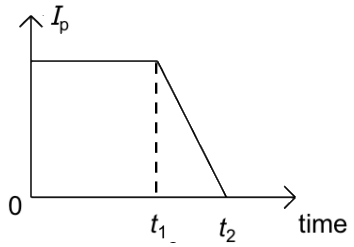
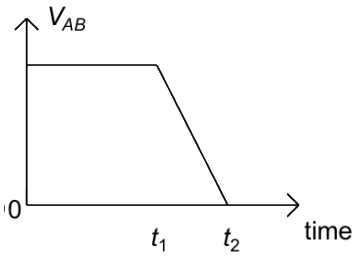


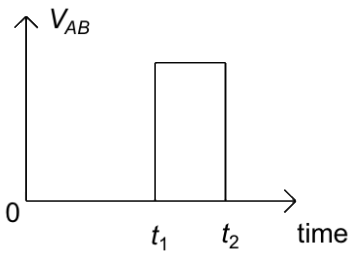
Fig. B

Which of the following sketches represents the variation of the voltage across the secondary coil V_{AB} with time?

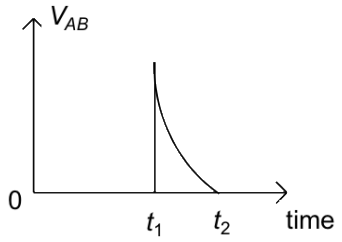
A



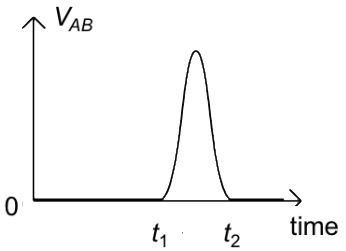
B



C



D



Answer: B

As the current in the primary coil changes, it will induce a current in the secondary coil due to the changing magnetic flux linkages in the secondary coil, according to Faraday's Law.

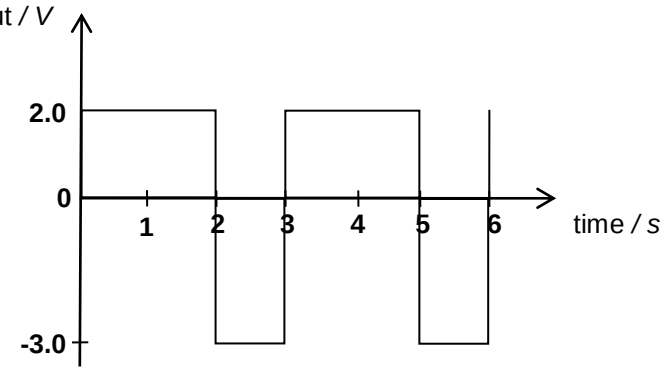
$$E = -\frac{d\Phi}{dt}$$

Ip /Is for an ideal transformer.

Since the current in the primary coil changes linearly from t_1 to t_2, so will the magnetic flux linkage in the primary (and secondary coil, as linked by the soft iron core). Therefore, according to the relationship above, the induced emf in the secondary coil will be a constant non-zero value during time period t_1 to t_2.

33 A 20 Ω resistor is connected to an AC power supply with a voltage output that varies from 2.0 V to – 3.0 V as shown on the graph below.

show an understanding and use the terms period, frequency, peak value and root-mean-square value as applied to an alternating current or voltage. L2



What is the average heating power dissipated in the resistor?

A 0.083 W **B** 0.28 W **C** 0.43 W **D** 0.65 W

Answer: B

$$Average\ power = \frac{V_{rms}^2}{R} = \frac{1}{20}\left(\frac{2^2 \times 2 + 3^2 \times 1}{3}\right)$$

$$= 0.28\ \text{W}$$

34 Which of the following statements about the wave-particle duality is true?

describe and interpret qualitatively the evidence provided by L2

electron diffraction for the wave nature of particles.

A The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that it is subatomic in size.

B The wave-particle duality suggests that every particle will have an associated wavelength when it moves, regardless of whether it has a mass or not.

C The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that they have a non-zero charge.

D The wave-particle duality suggests that every particle will have an associated wavelength when it moves, provided that it is undergoing quantum tunneling.

Answer: B

This principle is applied for all particles, regardless of mass, charge and size.

35 The fastest recorded tennis serve was measured to have a speed of (73.2 ± 0.1) m s^{-1} and an average tennis ball has a mass of 58.0 g.

What is the minimum uncertainty of its position?

show an understanding of and apply the Heisenberg position-momentum and time-energy uncertainty principles in new situations or to solve related problems. L2

A 9.09×10^{-33} m **B** 1.24×10^{-35} m **C** 9.09×10^{-36} m **D** 1.24×10^{-38} m

Answer: A

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x \geq \frac{h}{4\pi(\Delta p)}$$

$$\Delta x \geq \frac{h}{4\pi m(\Delta v)}$$

$$\Delta x \geq \frac{6.63\times10^{-34}}{4\pi(0.058)(0.1)}$$

$$\Delta x \geq 9.09\times10^{-33} m$$

36 Which of the following changes will increase the probability of a particle tunneling through a potential barrier?

apply the relationship transmission coefficient T ú exp(–2kd) for the STM in related situations or to solve problems. (Recall of the equation is not required.)

L2

A Increasing the width of the potential barrier

B Increasing the height of the potential barrier

C Shooting particles of a smaller mass at the potential barrier

D Decreasing the energy of the particles incident on the potential barrier

Answer: C

Looking at formula for the transmission coefficient, it can be seen that increasing the potential barrier height and width and decreasing the energy of the particles will decrease the probability of transmission. Only decreasing the mass will increase the probability.

.

37 Which of the following best describes the meaning of population inversion?

recall and use the terms spontaneous emission, stimulated emission and population inversion in related situations. L1

A Electrons are able to stay in such a state for a longer period.

B An atom in an excited state undergoes a transition to the ground state and emits a photon.

C The number of atoms at a lower energy state exceeds the number of atoms at a higher energy state.

D The number of atoms at a higher energy state exceeds the number of atoms at a lower energy state.

Answer: D

Option A is referring to a metastable state.
Option B is referring to the spontaneous emission of an electron
Option C is the atom in its natural state

38 Which of the following statements about a semiconductor diode in forward bias is incorrect?

discuss qualitatively the origin of the depletion region at a p-n junction and use this to explain how a p-n junction can act as a rectifier. L2

A Holes will move away from the p-n junction due to the external electric field.

B Electrons in the n-type semiconductor will cross steadily to the p-type semiconductor.

C The applied potential difference from the external source of e.m.f. opposes the junction potential.

D The n-type material of the diode is connected to the negative terminal of the external source of e.m.f.

Answer: A

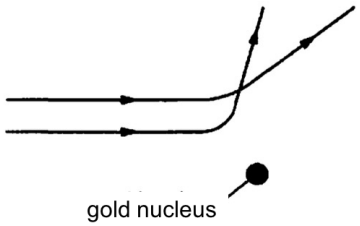
Holes will only move away from the diode in the reverse bias configuration. The remaining options describe the conditions and the mechanism of a forward bias flow. The n-type semiconductor will be connected to the negative terminal of the e.m.f. source, and this will lead to the mobile electrons experiencing an electric force that will allow them to move across the p-n junction.

39 Two alpha particles with equal energies are fired towards the nucleus of a gold atom.

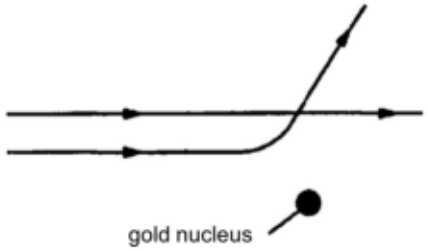
Which diagram could represent their path?

infer from the results of the α-particle scattering experiment the existence and small size of the nucleus. **L1**

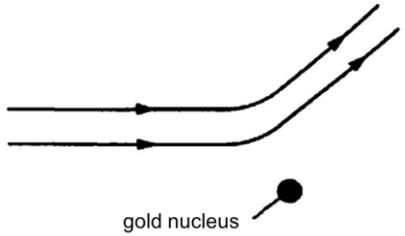
A



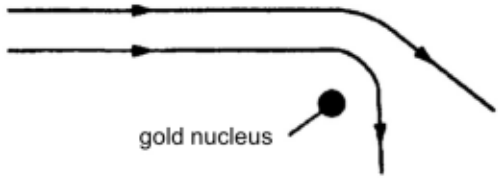
B



C



D



Answer: A

Due to the electric force of repulsion that decreases in magnitude as the distance between charged particles of the same charge increases, the angle of deflection will be lesser.

40 A newly prepared radioactive nuclide has a decay constant of 10^{-6} s^{-1}.

What is the approximate half-life of the nuclide?

solve problems using the relation λ = 0.693/$t_{1/2}$ L1

A 1 hour

B 1 day

C 1 week

D 1 month

Answer: C

$\lambda = \frac{\ln 2}{t_{1/2}}$

$t_{1/2} = \frac{\ln 2}{\lambda}$

$= \frac{\ln 2}{\lambda}$

$= \frac{\ln 2}{10^{-6}} = 6.93 \times 10^{6} \approx 8\ days$

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JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME			
CLASS	**2T**	**INDEX NUMBER**	

PHYSICS
9646/2
Paper 2
23 August 2016
1 h 45 min

Additional Materials: Answer Papers

READ THESE INSTRUCTIONS FIRST
Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

A **maximum** of **2 marks** will be **deducted** for wrong significant figures and incorrect/lack of units.

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

DIFFICULTY		
L1	L2	L3

SKILL			
S1	S2	S3	S4

FOR EXAMINER'S USE	
Q1	/ 6
Q2	/ 11
Q3	/ 10
Q4	/ 6
Q5	/ 13
Q6	/ 14
Q7	/ 12
SF/UNITS	
TOTAL	/ 72

This document consists of **18** printed pages

[Turn over]

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\pm \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

1 (a) A student wants to find the number of moles of nitrogen molecules in a reactor. In the high pressure reactor, a sample of nitrogen gas is kept at a pressure of $(5.0 \pm 0.2) \times 10^5$ Pa, with a volume of (100 ± 5) cm^3 and a temperature of (523 ± 5) K. The nitrogen in the reactor obeys the Ideal Gas Law, which is

$$PV = nRT$$

where P is the pressure of the gas, V is the volume of the gas, n is the number of moles of the gas, R is a constant and T is the temperature of the gas.

Determine the percentage uncertainty in calculating the number of moles of nitrogen molecules present in the reactor.

percentage uncertainty = …… % **[2]**

Solution:

$PV = nRT$

$n = \frac{1}{R}\frac{PV}{T}$

Therefore, percentage uncertainty,

$\frac{\Delta n}{n} = \frac{\Delta P}{P} + \frac{\Delta V}{V} + \frac{\Delta T}{T}$ (R is constant and assumed to have no absolute uncertainty) **M1**

$\frac{\Delta n}{n} = \frac{0.2}{5.0} + \frac{5}{100} + \frac{5}{523}$

$\frac{\Delta n}{n} = 0.0996$

$\frac{\Delta n}{n} = 10\%$ **A1**

(b) Tempered glass screen protectors are made up of silicon dioxide (one silicon atom with two oxygen atoms) molecules.

Estimate the number of moles of silicon atoms in a 0.5 mm thickness tempered glass screen protector for a mobile phone. Show your working and reasoning clearly.

moles of silicon atoms = …… mol **[4]**

Solution: **M1**

An estimated area of a mobile screen is about 6 cm by 11 cm.
(Accepts 5 to 7 cm by 10 to 12 cm. ±1 cm at both ends)
Volume of tempered glass screen protector,

$V = 0.06 \times 0.11 \times 0.0005$

$V = 3.30 \times 10^{-6}\ \text{m}^3$

The diameter of 1 atom is approximately 0.1 nm. Therefore, the estimated volume of a spherical atom, **M1**

$V_{atom} = \frac{4}{3}\pi r^3$

$V_{atom} = \frac{4}{3}\pi\left(0.05 \times 10^{-9}\right)^3$

$V_{atom} = 5.24 \times 10^{-31}\text{m3}$

Therefore, the total number of atoms in the screen protector,

$$n = \frac{V}{V_{atom}} = \frac{3.30\times10^{-6}}{5.23\times10^{-31}} = 6.30\times10^{24}$$ **A1**

Hence, the number of moles of silicon atoms, **C1**

$$n_{silicon} = \frac{6.30\times10^{24}}{3\times6.02\times10^{23}} = 3.49$$

General method of finding number of silicon atoms is worth 1 mark.

2 An archer shoots an arrow to hit a target board secured firmly on a stand as shown in Fig. 2.1. The point where the arrow is released is considered to be levelled with the target as measured from the ground.

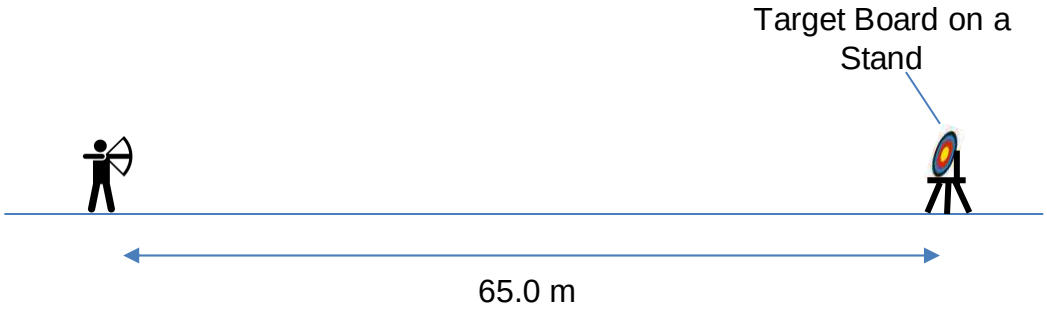


Fig. 2.1

The archer is standing still 65.0 m away from the target. The arrow has a mass of 880 g.

(a) (i) Explain why, in order for the arrow to hit the bull's eye, the archer has to aim the arrow at an angle above the target, and not directly at the target.

[2]

Solution:

There will be a **constant downward force** on the arrow as it travels through the range of 65.0 m to hit the target, thus, changing the arrow's vertical velocity. **B1**

Aiming the arrow at an angle above the target allows the arrow to go in a **projectile motion**, such that the arrow's vertical speed can decrease as It moves upwards initially, reach zero, and then increase downwards through the 65.0 m range before landing at the levelled target. **B1**

Aiming directly would cause the arrow to increase in the downward velocity and hit below the target.

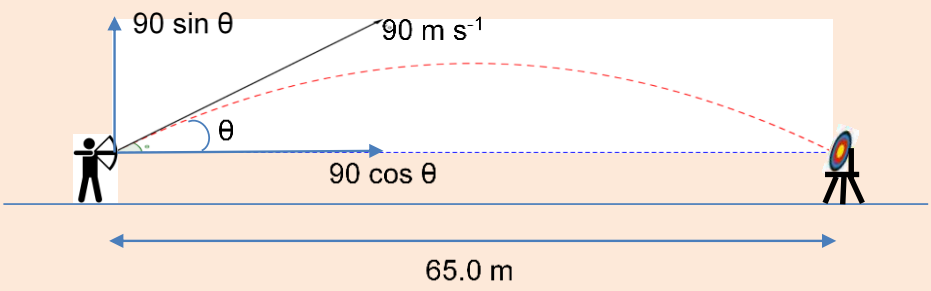
(ii) The arrow leaves the archer's bow at an angle less than 45° and with an initial velocity of 90.0 m s^{-1}. Determine the angle above the horizontal that the archer has to release the arrow such that it can hit the centre of the target.

You may find the following equation useful: $\sin 2x = 2\sin x \cos x$

angle above horizontal = …… ° **[4]**

Solution:

M1



M1

Let θ be the angle above horizontal that the archer is aiming as shown above (angle shown is exaggerated). **M1**

Consider the horizontal direction only, taking right as positive,

$$s_x = u_x t$$

$$t = \frac{65.0}{90\cos\theta} \quad (1)$$ **A1**

Consider the vertical direction only, taking up as positive,

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$0 = 90\sin\theta t - 4.905t^2$$

$$t = \frac{90\sin\theta}{4.905} \quad (2)$$

Sub (1) in (2),

$$\frac{65.0}{90\cos\theta} = \frac{90\sin\theta}{4.905}$$

$$4050(2\sin\theta\cos\theta) = 65.0 \times 4.905$$

$$\sin 2\theta = \frac{65.0 \times 4.905}{4050}$$

$$\theta = 2.26°$$

(b) The target board and its stand are resting on a frictionless ground. When the arrow strikes the target board, the arrow, target boards and stand move together as one body along the ground.

(i) Explain why the total momentum of the system consisting of the target board, stand and arrow in the horizontal direction along the ground is conserved before and after the arrow strikes the target board, whereas the total momentum of the system in the vertical direction is not conserved.

[1]

Solution:

There is **no external force in the horizontal direction**, but there is **an external force** – normal contact force on the stand by the ground – **in the vertical direction**. **B1**

(ii) The target board and the stand have a total mass of 12.2 kg and are initially at rest before the arrow strikes them.

Determine the final speed of the arrow after it has struck the target board.

speed = …… m s^{-1} **[2]**

Solution:

By Principle of Conservation of Linear Momentum, taking right as positive,

$$m_{arrow}u_1 + m_T u_2 = m_{Total} v$$

$$v = \frac{m_{arrow}u_1 + m_T u_2}{m_{Total}}$$

$$v = \frac{(0.880)(90\cos 2.26) + (12.2)(0)}{0.880 + 12.2}$$ **M1**

$$v = 6.05 \text{ m s}^{-1}$$ **A1**

(iii) State the momentum of the archer along the frictionless ground immediately after the arrow is shot off from the archer. Explain your answer.

[2]

Solution: **B1**

By principle of conservation of linear momentum, **considering the system of archer, arrow and target**, the initial momentum of zero must be the same as the final momentum of the system.

Therefore, the momentum of the archer must be numerically equal to the final momentum of the arrow and target, which is $p = (0.880 + 12.2)(6.05) = 79.1 \text{kg m s}^{-1}$, **towards the left.** **B1**

3 A loudspeaker operating at 86 Hz is producing a wave of wavelength 4.0 m.

At a particular instant of time,

Fig. 3.1 shows the graph of displacement, *s*, against distance, *x*, of the air particles.
Fig. 3.2 shows the regions of rarefaction and compression.
Fig. 3.3 shows the pressure variation with position along the wave at an instant of time.

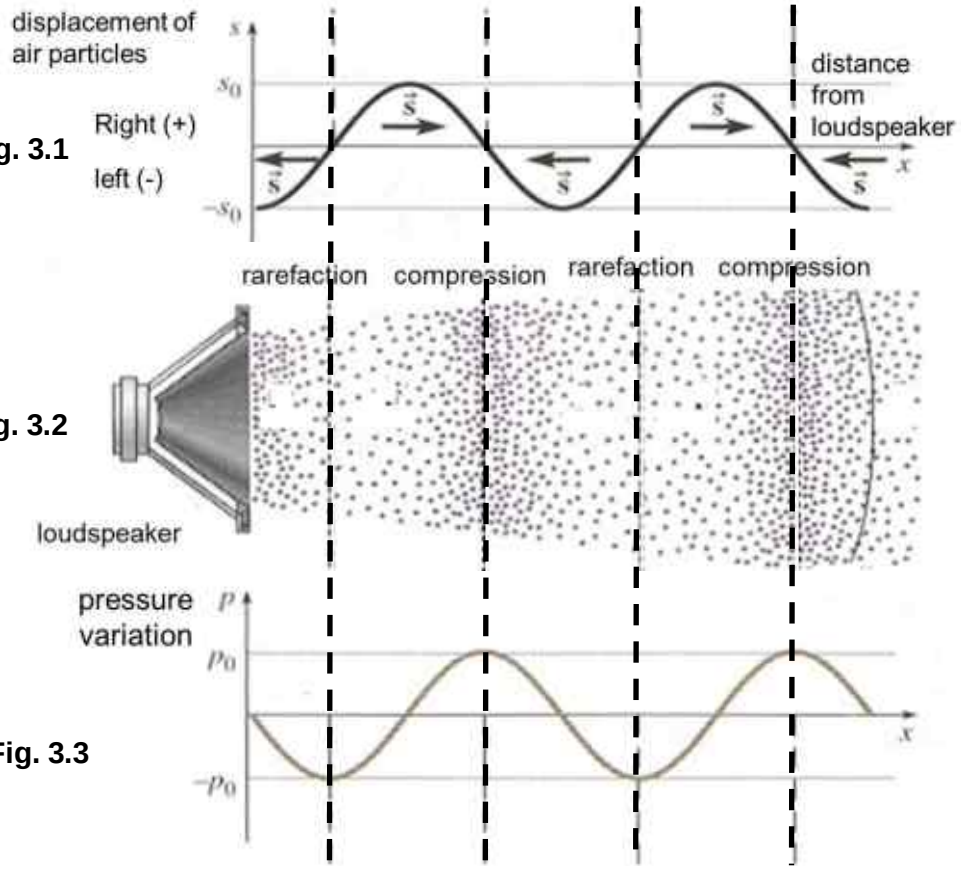


Fig. 3.1

Fig. 3.2

Fig. 3.3

(i) Determine the speed of the wave.

speed of wave = …….. m s^{-1} **[2]**

Solution:
$v = f\lambda$
$= 86 \times 4$ **M1**
$= 344\ m\ s^{-1}$ **A1**

(ii) State and explain how you would deduce the velocity of the rarefaction and compression.

[2]

Solution:
Rarefactions and compressions are produced when the air particles are displaced by the wave.
Rarefactions and compressions **move in the direction** in which the **energy of the wave travels**. Their speed is the speed of the wave found in part (i) or **344 m s^{-1}**. **B1** **B1**

(iii) Another identical loudspeaker is now placed 20 m away to the right of the first loudspeaker shown in Fig. 3.2. Both loudspeakers are facing each other.

1. Explain the formation of the stationary (standing) wave between the loud speakers.

[2]

Solution:
The waves from the two loud speakers **travelling in opposite directions undergo superposition** to produce the stationary wave since they have the **same frequency/wavelength nature and speed.** **B1** **B1**

2. Determine the distance between any two consecutive nodes in the stationary wave formed.

[2]

distance = …….. m

Solution:
Inter-nodal distance = $\frac{\lambda}{2}$ **M1**
$= \frac{4}{2} = 2m$ **A1**

3. By describing the movement of molecules in a stationary sound wave, explain where the air pressure varies the least.

[2]

Solution:
The molecules at the **displacement antinode** **B1**
At the displacement antinode, **the relative separation of neighbouring air molecules are about the same** and hence this coincides with the pressure node where air pressure varies the least. **B1**

4 **(a)** Define *potential difference*.

[1]

work done per unit charge to convert electrical energy to other forms of energy. B1

OR

energy transferred from (electrical to other forms) per unit charge B1

(b) The circuit shown in Fig. 4.1 is used to compare potential differences of cells.

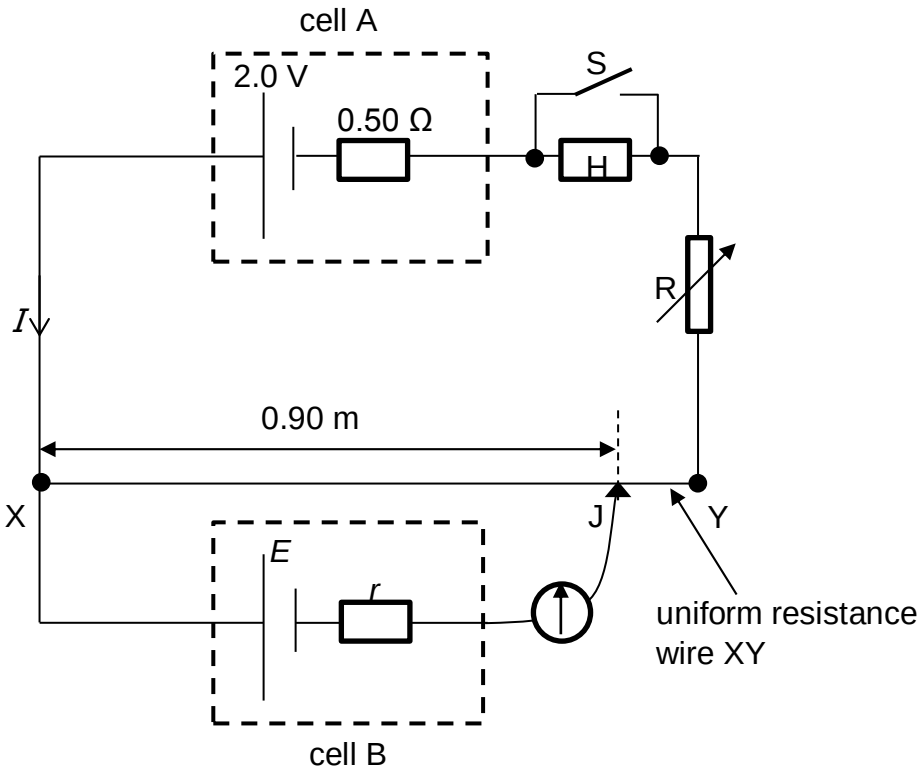


Fig. 4.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. When switch S is closed, the current through cell A is I. Cell B has e.m.f. E and internal resistance r.

The current through cell B is made zero when the movable connection J is adjusted such that the length of XJ is 0.90 m. The variable resistor R has resistance 1.5 Ω while the fixed resistor H has resistance 1.0 Ω

(i) Determine the value of E.

E = …….. V **[3]**

Solution

$2.0 = I \times (4.0 + 1.5 + 0.5)$ C1

$I = 0.333$ A (allow 2 s.f.)

$R = \frac{0.9}{1.0} \times 4 \ (= 3.6)$ M1

$E = IR = 0.333 \times 3.6 = 1.20$ V A1

(If factor of 0.9 not used, then 2/3 marks)

(ii) When switch S is opened, determine quantitatively if the balance length XJ exists for this setup no change in the values of cell B. **[2]**

With switch S opened, the potential difference across XY is now

$$V_{XY} = \frac{4.0}{4.0 + 0.5 + 1.5 + 1.0} \times 2 = 1.14 \text{ V}.$$

B1

However the e.m.f. of cell B is 1.20 V (remains constant) which is larger than the potential difference across XY.

B1

Thus it would not be possible to determine the balance length XJ.

5 Fig. 5.1 shows a simplified circuit diagram of the apparatus used in an experiment involving a photocell and a copper resistance wire XY to demonstrate the photoelectric effect. Scientists were particularly interested in the effects of the *intensity* and *frequency* of the electromagnetic radiation on the current (measured by the ammeter **A**) due to the emission of the photoelectrons.

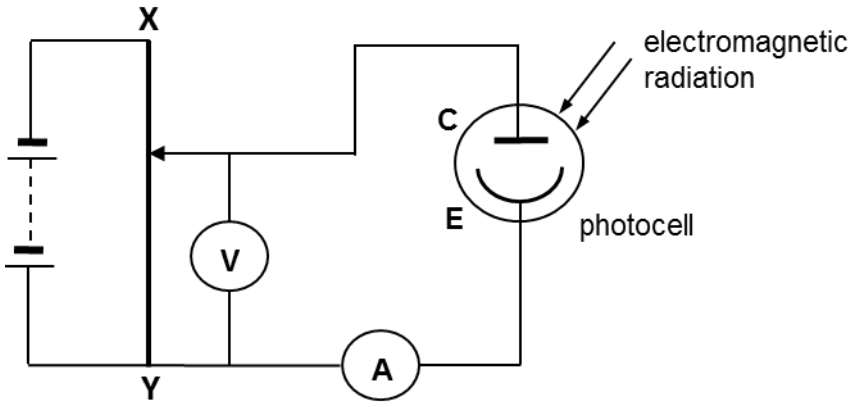


Fig. 5.1

(a) State what is meant by the *photoelectric effect.* **[1]**

Solution

It is a phenomenon that results in the **ejection of electrons** from a **metal surface** when electromagnetic radiation of **high enough frequency** is shone on it. **B1**

(b) The Einstein's Equation for the photoelectric effect can be written as

$$E = \Phi + E_K$$

State the quantity represented by each symbol in the equation.

[3]

Solution

E: the energy of a photon **B1**

Φ: work function energy **B1**

E_K: the maximum kinetic energy that an electron will possess after leaving the metal surface **B1**

(c) For a *given intensity* and *frequency* of EM radiation, the following graph of current (I) against the applied potential difference (V) was obtained as shown in Fig. 5.2.

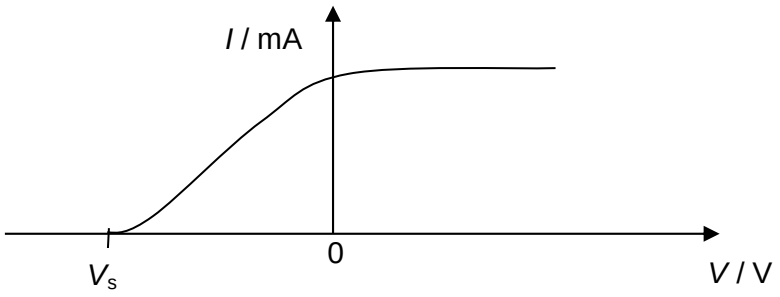


Fig. 5.2

(i) Explain

1. why there is a current registered in the ammeter even though the applied voltage across plates E and C is zero. **[3]**

Solution

As **EM radiation is still incident on the emitter plate** (*or* as photons are still incident on the emitter plate), the surface electrons will still be gaining energy from the photons. So long as the **photoelectrons are emitted with a non-zero kinetic energy**, there is **a possibility of them reaching the collector plate** and hence a non-zero current will be registered in the ammeter. **B1** **B1** **B1**

2. why there is no change in the current despite an increasing positive applied voltage when the current reaches a maximum value **[3]**

Solution

At a given intensity, the **rate of photons incident onto the emitter is fixed**. Since the **rate of photoelectron emission is proportional to the rate of photon incidence, the rate of photoelectron emission is also fixed**. **B1** **B1**

At **maximum current value, increasing positive applied voltage will thus not affect the rate of photoelectrons reaching the collector** if the intensity of radiation is fixed. **B1**

3. the changes, if any, in the graph in Fig. 5.2 when the copper resistance wire is now replaced with one made of gold. **[3]**

Solution

The value of the **maximum current is proportional to the intensity** and the **stopping potential is dependent on the maximum KE of the photoelectrons, which is in turn dependent on the frequency of the EM radiation**. **M1**

By changing the material of the resistance wire, it **only affects the potential gradient of the wire**. **M1**

Since there is no change to the intensity and frequency of the EM radiation, there will **not be a change to the graph in any way**. **A1**

6 Multi-bladed low-speed wind turbines (windmills) similar to the one shown in Fig. 6.1 have been used since 1870, particularly for pumping water on farms.

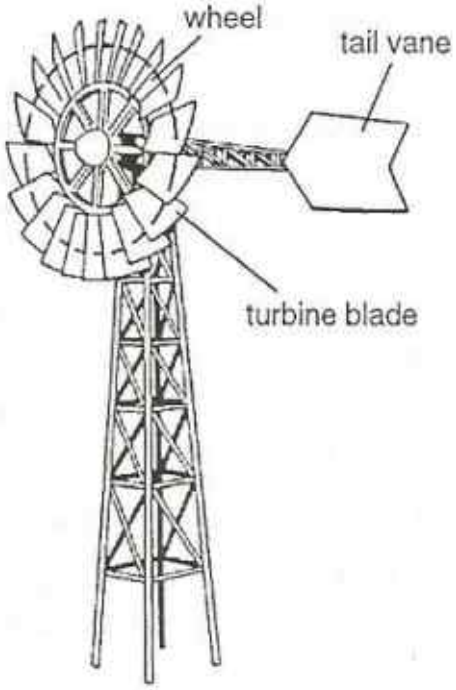


Fig. 6.1

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.

Fig. 6.2 shows the variation of P, the output power of windmills similar to that shown in Fig. 6.1 with the diameter of the wheel for different wind speeds, v.

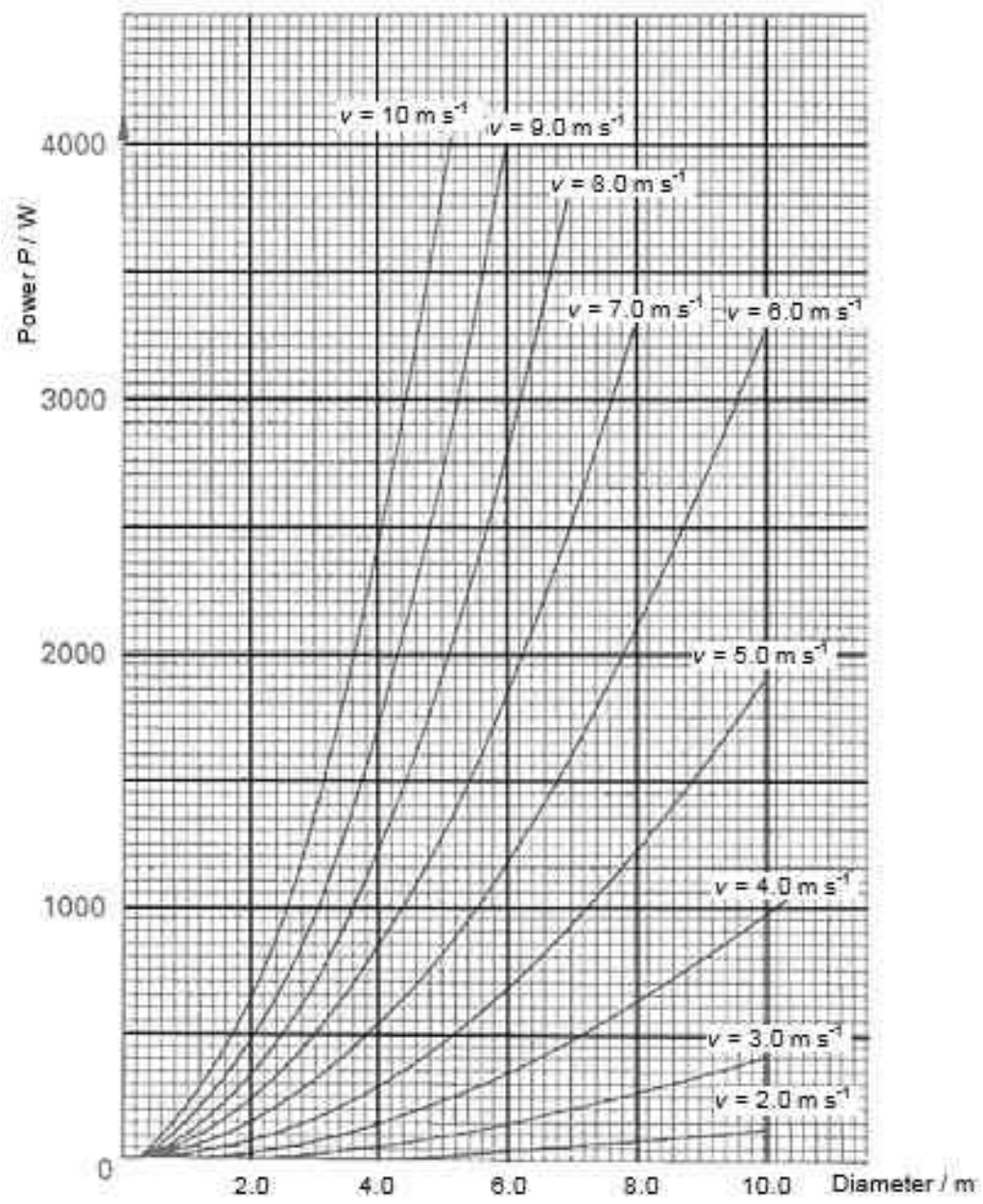


Fig. 6.2

(a) 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.

(i) Use Fig. 6.2 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) = ... **[1]**

For diameter = 6.0 m and v = 3.0 m s^{-1},
P = 150 W
lg P = 2.2

B1

(ii) The graph of lg (P / W) against lg (v / m s^{-1}) is plotted on Fig. 6.3.

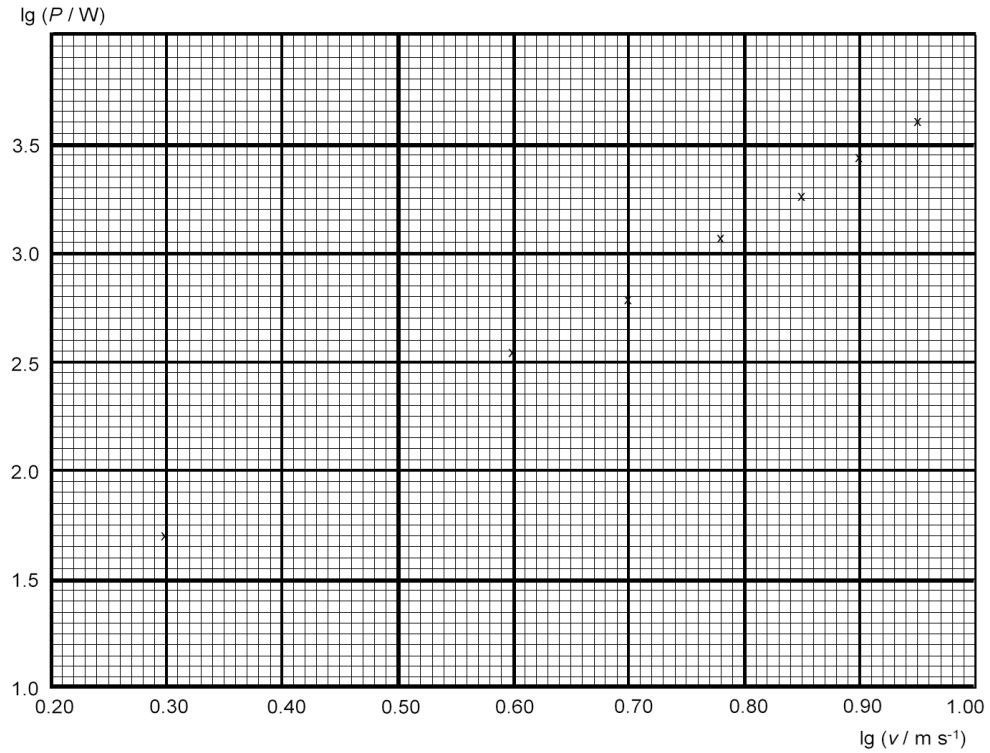


Fig 6.3

On Fig. 6.3,

1. plot the point corresponding to a wheel diameter of 6.0 m and a wind speed of 3.0 m s^{-1}, and **[1]**

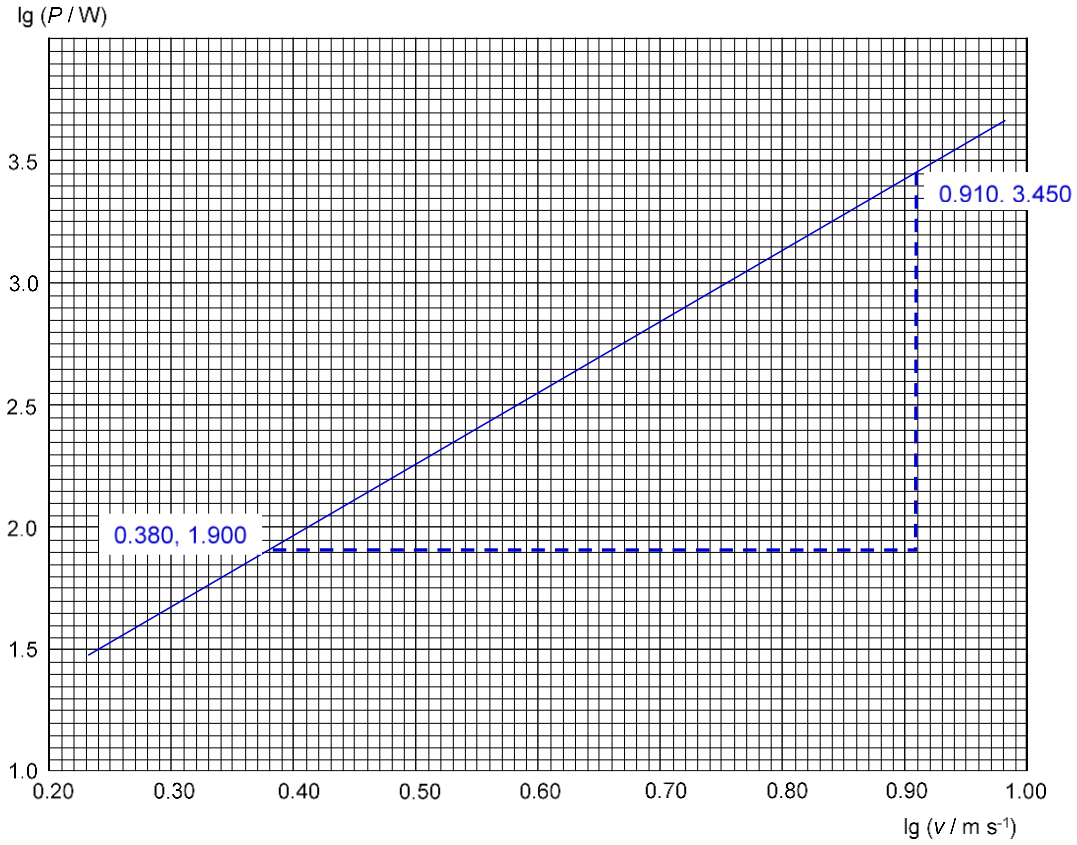
2. hence, draw the line of best fit for the points **[1]**

Solution:

lg v = lg (3.0) = 0.48 **B1**

[B1] for correct point (0.48, 2.2) plotted.

[B1] for suitable best-fit-line drawn. **B1**



(iii) Use the line drawn in **(c)(ii)** to determine the magnitudes of

1. the constant *n,* and

n =..... **[2]**

Solutions: **M1**

n = Gradient = $\frac{3.450-1.900}{0.910-0.380}$

= 2.93 **A1**

2. the constant, *k.*

k = ... **[2]**

Solutions: **M1**

Sub (0.380, 1.900) and gradient = 2.93,
1.900 = (2.93) (0.380) + y-intercept
y-intercept = 0.7866
lg k = 0.7866
k = 6.12 **A1**

(b) On a particular day, the wind speed is 8.0 m s^{-1}.

(i) Estimate the volume of air that reaches the 6.0 m diameter wheel of the windmill per second.

volume of air per second =.....m^3 s^{-1} **[2]**

Solution:
Considering the air moving through the blades of the windmill is approximately a cylindrical volume, **M1**

$$\frac{\text{volume}}{\text{time}} = \frac{\pi r^2 x}{t}$$

$$\frac{\text{volume}}{\text{time}} = \pi r^2 v$$ **A1**

$$\frac{\text{volume}}{\text{time}} = \pi\left(\frac{6.0}{2}\right)^2 8.0$$

$$\frac{\text{volume}}{\text{time}} = 226.2 = 230\ \text{m}^3\ \text{s}^{-1}$$

(ii) The density of air is about 1.3 kg m^{-3}. Estimate the kinetic energy of the volume of moving air in **(b)(i)**.

kinetic energy of the air = …….. J **[2]**

Solution:

Per second,

Kinetic energy of the air moving past

$$= \frac{1}{2}mv^2 = \frac{1}{2}(\rho V)v^2$$ **M1**

$$= \frac{1}{2}(1.3)(226.2)(8)^2$$

$$= 9409.92 = 9400\ \text{J}$$ **A1**

(iii) Use Fig. 6.2 to find the fraction of the power from the moving air in **(b)(ii)** that is converted into useful power.

fraction of power = …… **[2]**

Solution:

Part of the kinetic energy of the moving air is converted into rotational kinetic energy of the turbines which is then converted into electrical energy.

From Fig. 6.2, at v = 8.0 m s^{-1}, diameter = 6.0 m,
Actual useful power output, P = 2750 W **M1**

Assuming the air loses *all* its KE to the turbines,
Total power input = 9409.92 W (from (b)(ii))

$$\frac{\text{useful power output}}{\text{total power}} = \frac{2750}{9409.92} = \mathbf{0.29\ (2\ s.f.)}$$ **A1**

(c) State one other factor, besides wind speed and diameter of wheel that are likely to influence the output power of the windmill.

[1]

Solution:

[B1] marks for any of the points:

- Height of the windmill.
- Location of the windmill.
- Type of material used for the blades.
- Shape of the blades.

B1

- Surface area of the blade.
- Friction between the wheel and the axle.

7 Gamma ray (γ-ray) is a type of ionising radiation. The absorption of γ-ray as it passes through a metallic material increases as the thickness of the material increases. The count rate of the γ-ray, *C*, penetrating through a material depends on the thickness *d* of the material.

You are provided with a Cobalt-60 source, a Geiger-Müller Tube connected to a datalogger that measures the total number of counts in a fixed time period and a number of lead slabs of standard business card size to act as absorbers of γ-rays. Cobalt-60 is a radioactive source that emits both β rays and γ-rays at the same time. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between *C* and *d*.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay special 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 *C* and *d* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment. **[12]**

Solution:

1. Defining the Problem

Criteria:

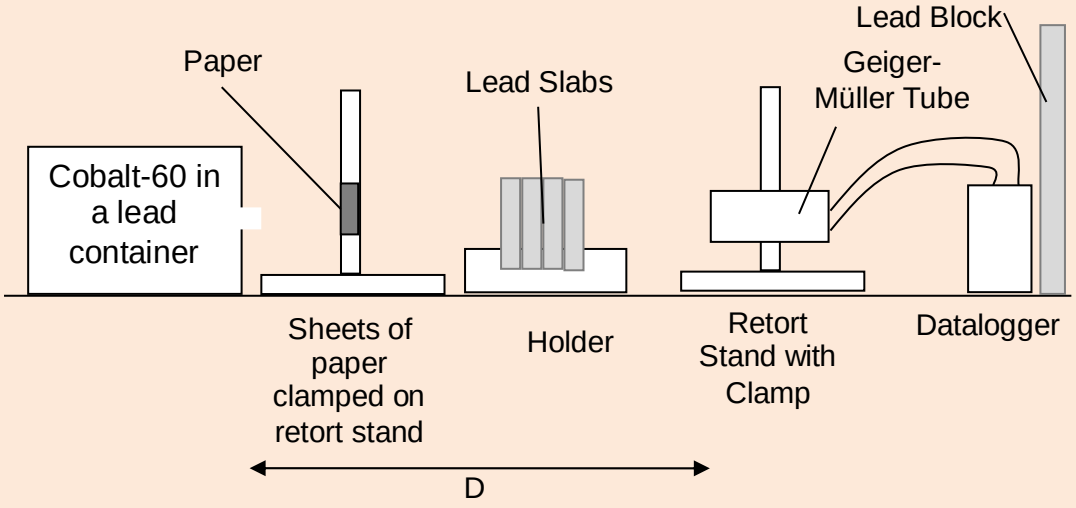
a) Identification of 1 IV, 1 DV and at least 2 CVs.
b) All IV, DV and CVs are physical quantities
c) Variables are specific and clear

IV: Thickness of lead slabs, *d*

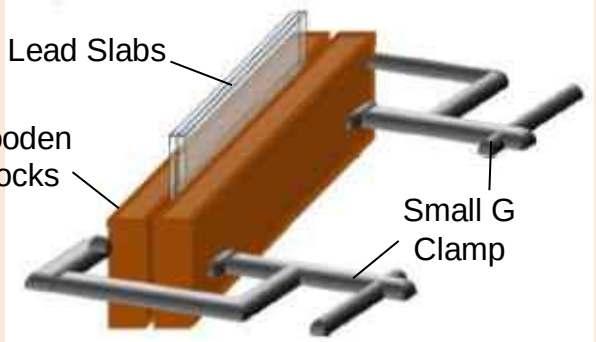
DV: Count rate of γ-rays after passing through the leab slabs, *C*

CVs: Distance between source and Geiger-Müller Tube, initial Activity / Count Rate of Cobalt-60 source

2. Diagram



More detail on the lead slab with holder,



3. Procedures

1. Set up the apparatus as shown in the diagram, first without the lead slabs. Measure the length between the Cobalt-60 source and the Geiger-Müller (GM) tube with a metre rule D = 30 cm. Secure the GM tube on a retort stand so as to keep D constant throughout the experiment.
2. The **count rate at the GM tube location can be determined by using the GM tube connected to the datalogger**. Switch on the GM tube connected to a datalogger for **1 min** to measure the number of counts shown on the datalogger. **Use a stopwatch to measure the time taken**. Reset the number of count and measure the counts for 1 min again**. Calculate the average counts and take the average total number of counts divided by 60 s to get the average count rate as measured by the GM tube.**
3. Perform step 2 with the Cobalt-60 source in the lead container. Record the count rate as C_{Cobalt}. **Place a few sheets of paper** in between the Cobalt-60 source and the GM tube and repeat step 2. There should be a decrease in the count rate as the β-ray is blocked by the sheets of paper. **Increase the number of sheet of paper until the point where an additional sheet of paper does not decrease the count rate.** At this point, only γ-rays from the source reaches the GM tube.
4. Remove the Cobalt-60 source from the lead container and repeat step 2. Record this count rate as the **background count rate**, $C_{background}$.
5. Insert the Cobalt-60 source and repeat step 2 to measure the initial count rate of the Cobalt-60 γ-rays together with the background count rate. Minus the $C_{Background}$ from the count rate obtained to get the initial count rate of the Cobalt-60 γ-rays $C_{initial}$. The paper is still placed after the source to block out the β rays.
6. Measure the **thickness of 5 lead slabs using a Vernier Caliper/micrometer screw gauge**. Measure the thickness at least 3 times at different parts of the lead slab and take the **average thickness of the 5 slabs**. Record the thickness of the lead slabs as *d*.
7. Place the 5 lead slabs in between the Cobalt-60 source and the GM tube. Perform step 2. Minus the count rate obtained in this way with the background count rate, $C_{background}$ to obtain *C*.
8. Repeat step 7 to obtain a second reading for 5 lead slabs so as to get an average reading for *C*.
9. Repeat step 6 to 7 by **increasing the number of lead slabs**, 2 at each time, until **at least 6 sets of readings** for thickness *d* and count rate *C* are obtained.
10. Assume that the relationship between *C* and *d* is given by,
$$C = C_{initial} e^{-kd}$$
where *k* is a constant. Therefore,
$$\ln C = \ln C_{initial} - kd$$
11. **Plot a graph of ln *C* against *d*. A straight line graph with negative gradient –*k* and vertical intercept ln $C_{initial}$ is expected**

4. Additional Details

- Account for background radiation count rate using the method described in step 2 of the procedure.

- Conduct a preliminary experiment to determine a suitable range of values. It is to ascertain whether a distance of 30 cm would be able to get sensible reading. Furthermore, using 5 lead slabs at the start is arbitrary. A preliminary experiment can determine the range for the number of lead slabs used so that at least 6 sets of readings can be obtained.
- Use the same Cobalt-60 source for all sets of readings so as to keep constant the initial activity/count rate.
- After step 9, remove the lead slabs and perform step 2, to check that the initial count rate remains constant. Change to a new source if it is not at the same count rate and repeat the whole experiment.
- Before the start of the experiment, use a laser to align the apparatus first before using Cobalt-60 as the source.

5. Safety

Any action plan to account for the safety of the experimenter and the people around during the experiment. Any one, but not limited to, the following:

a) Handle the radioactive Cobalt-60 source with tweezers and gloves to prevent direct contact with the radioactive source and prevent it from entering the body.
b) Place the Cobalt-60 source in a lead container at all times to prevent unnecessary exposure to ionizing radiation.
c) Have warning signs around the experiment set up to prevent anyone from coming in contact with the radioactive source or coming into the path of the β-rays and γ-rays radiation.
d) Place a large thick lead slab after the GM tube to absorb the stray β-rays and γ-rays in the direction such that there is no leaking of radiation out of the set up.

(The above plan is a sample plan. The marking criteria is shown on the column on the right.)

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME					
CLASS	**2T**	**INDEX NUMBER**			

PHYSICS [SOLUTIONS]

9646/3
PAPER 3
25 August 2016
2 hours

Additional Materials: Answer Papers

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
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 in **Section A**, and **TWO** out **three** questions in **Section B.**

Circle the question number of the questions that you have attempted in **Section B** in the summary table at the bottom of this page.

A **maximum** of **2 marks** will be **deducted** for wrong significant figures and incorrect/lack of units.

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

DIFFICULTY		
L1	L2	L3

SKILL			
S1	S2	S3	S4

FOR EXAMINER'S USE	
Q1	/ 6
Q2	/ 6
Q3	/ 6
Q4	/ 12
Q5	/ 10
SECTION A	/ 40
Q6	/ 20
Q7	/ 20
Q8	/ 20
SECTION B	/ 40
SF/UNITS	
TOTAL	/ 80

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS 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,	ϕ	=	$-G\,m / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^{\,2} - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\,\pi\,\varepsilon_0\,r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

SECTION A (40 marks)

Answer all questions in Section A.

1 A ski jumper lands 96 m from his take off point after taking off at an angle θ to the horizontal as shown in Fig. 1.1 below. The slope is at an angle of 40° and the jumper is in the air for 4.3 s.

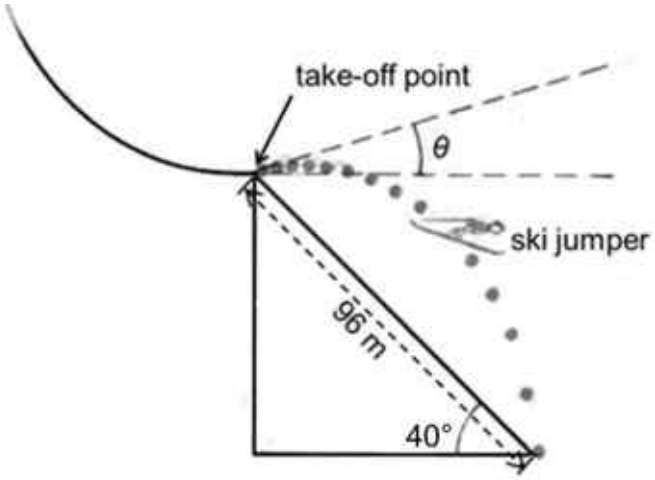


Fig. 1.1

(a) Assuming that air resistance is negligible, determine

(i) the vertical distance from take-off to landing,

vertical distance = ... m **[1]**

Solution:
$s_y = 96.0 \sin 40° = 61.7$ m (or 62 m) **B1**

(ii) the vertical component of the take-off velocity.

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

Solution:

Taking upwards as positive,
$S_y = u_y t + ½ at^2$
$-61.7 = u_y(4.3) – ½ (9.81)(4.3)^2$ **M1**
$4.3\ u_y = 90.69 – 61.7 = 28.99$
$u_y = 6.74$ m s^{-1} **A1**

(b) In practice, air resistance is not negligible.

Describe qualitatively the effect of air resistance on the variation, if any, of the component of velocity in

(i) the horizontal direction.

[1]

Solution:
The magnitude of the velocity in the horizontal direction **<u>decreases at a decreasing rate</u>.**

(This is because air resistance becomes smaller with time due to the decreasing horizontal speed.) **B1**

(ii) the vertical downward direction.

[2]

Solution:
Component of velocity in the vertical direction at the start equals zero (when ski jumper is at highest height).

The vertical downward velocity's **magnitude increases** **B1**
at a **decreasing rate**. **B1**

(At the start, it increases at the acceleration of free fall, thereafter, it increases slower than the acceleration of free fall. (This is because the air resistance opposing the velocity increases as the object's speed increases, thus reducing the resultant downward force with time.)

2 (a) State the first law of thermodynamics.

[1]

Solution:
The increase in internal energy of a system is equal to sum of the thermal energy supplied to the system and external work done on the system. **B1**

(b) An ideal gas undergoes a cycle of change, A → B → C → A, as shown in Fig. 2.1.

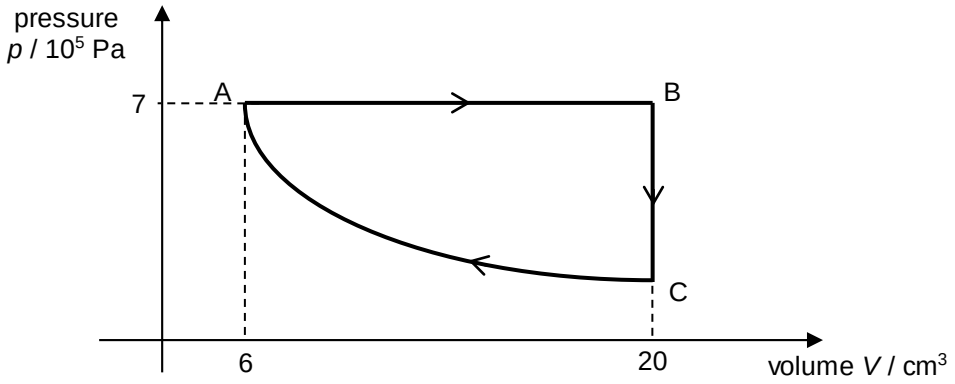


Fig. 2.1

(i) Calculate the work done by the gas during the change A → B.

work done by the gas = …….. J **[2]**

Solution:
$W = p\Delta V$
$W = \left(7\times10^{5}\right)\left[\left(20-6\right)\times10^{-6}\right]$ **M1**
$W = 9.80\,\text{J}$ **A1**

(ii) Fig. 2.2 is a table of energy changes during one complete cycle. Complete Fig. 2.2.

section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A → B			
B → C	-18.0		
C → A	0.00	3.30	

[3]

Fig. 2.2

Solution:

section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A → B	$\Delta U=Q+W$. Hence $Q=\Delta U-W$= 14.7- (-9.80)=24.5	-9.80 (From b(i). Since it is "on" gas, a negative sign is necessary.)	As it is a cyclic process, the sum of increase of internal energy is 0. Therefore, ΔU=0+18.0-3.30=14.7
B → C	-18.0	As B → C is an isovolumetric process, W = 0.00	$\Delta U=Q+W$=-18.0 +0.00=-18.0
C → A	0.00	3.30	$\Delta U=Q+W$=0.00+3.30 =3.30

3 A charged particle of mass m and charge $-q$ is travelling through a vacuum at a constant speed v. It enters a uniform magnetic field of flux density B. The initial angle between the direction of motion of the particle and the direction of the magnetic field is 90° as shown in Fig. 3.1 below.

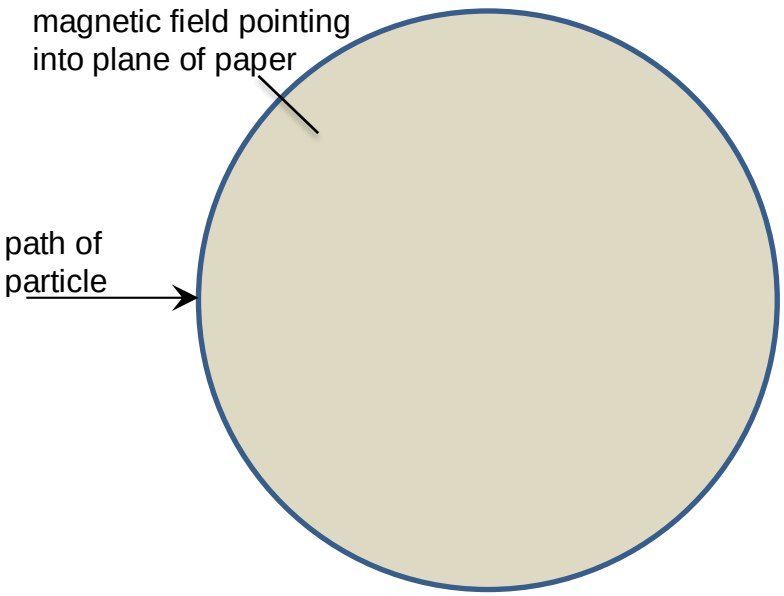


Fig. 3.1

(a) Explain why the path of the particle in the magnetic field is the arc of a circle with a fixed radius.

[3]

The magnitude of the magnetic force due to magnetic field is constant. **B1**

The direction of this force is always normal to the direction of its motion/velocity. **B1**

This force provides the centripetal force hence an arc of a circle is the path it takes **B1**

(b) The radius of the arc in **(a)** is r. Show that the specific charge of the particle (which is defined as the ratio $\frac{q}{m}$ of its charge to its mass) is given by the expression

$$\frac{q}{m} = \frac{v}{Br}$$

[1]

The magnetic force provides the centripetal force

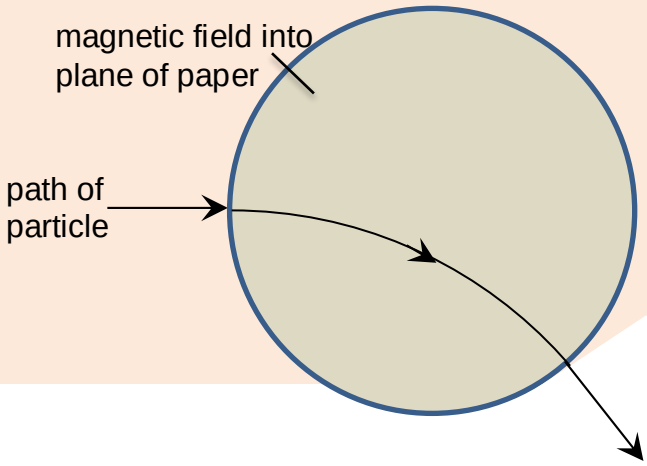
$$Bqv = \frac{mv^2}{r}$$ **M1**

Hence, $\frac{q}{m} = \frac{v}{Br}$ **A0**

(c) Sketch the path of the particle as it enters and subsequently emerges from the field on Fig. 3.1

Path upon entering and exiting the field must be tangent to arc of the circular path in the magnetic field. **M1**

Sketch of path in the field is a curved path, with constant radius, and in the direction the towards bottom of page. **A1**



4 (a) When an electric current is passed through a thin p-type semiconductor slab placed in a uniform magnetic field, a potential difference is set up across the sides of the slab. The voltage measured across both sides is known as the Hall Voltage.

Fig. 4.1 shows a slab with an electric current I passing through it placed perpendicularly to a magnetic field B and the voltmeter measures a Hall Voltage V_H across the sides X and Y.

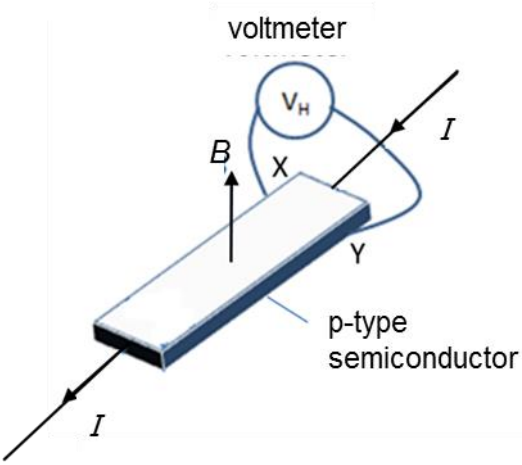


Fig 4.1

(i) Using band theory, explain why a p-type semiconductor has a higher conductivity than an intrinsic semiconductor.

[3]

Solution:

Impurities from a Group 3 element (such as Boron) is added to an intrinsic semiconductor, and this **increases the concentration of holes in the semiconductor**. **B1**

These holes occupy an extra energy level in the forbidden band between the valence and conduction band and **B1**

less energy is required to excite electrons from the valence band to fill the holes in the extra energy level **B1**

(ii) State which side of the slab, X or Y, is at a higher potential.

[1]

Solution:

Side X **B1**

(iii) Explain the reasoning for your answer in part **(ii).**

[2]

Solution:
As the **positively-charged** holes flow through the conductor, they experience a **magnetic force towards X** as dictated by **Fleming's Left Hand Rule**. **B1**

The holes accumulate on Side X and therefore, **this side is more positively charged** and is at a higher potential **B1**

(b) Describe the formation of the depletion region in a p-n junction.

[4]

Solution:
Electrons are the majority charge carriers in n-type semiconductors. Holes, are the majority charge carrier in the p-type semiconductor. **B1**

Electrons near the junction diffuse into the p-type semiconductor due to the difference in concentration, **while holes diffuse from the p-type into the n-type semiconductor also due to the difference in concentration**. **B1**

The electrons and holes recombine and the **n-type semiconductor has a net positive charge and the p-type semiconductor acquires a net negative charge.** **B1**

Thus, **an electric field and a potential difference is established at the junction**, with the n side at a higher potential relative to the p side, and **this prevents further diffusion of electrons forming a depletion layer.** **B1**

(c) State **two** conditions required for the production of a consistent laser beam.

[2]

Solution (any 2 answers):

The upper energy level involved in the lasing process must be in a metastable state: electrons at this level of energy state have longer lifetime than 10^{-8} s. This is to ensure that population inversion can be established **B1**

Atoms must attain population inversion: more atoms in the excited state as compared to those in the ground state. This is to ensure that the number of photons emitted is greater than the number of photons absorbed **B1**

Stimulated emission must take place during which a second photon, with the same energy level (E2 – E1) is being emitted. This produces 2 coherent photons having the same direction, phase and plane of polarization **B1**

5 (a) State **one** similarity and **one** difference between the properties of electric fields and gravitational fields.

[2]

Solutions:

B1

Similarities (any 1):

<u>The strength of the fields (force) varies by the inverse square of the distance</u> between the source and point in the field.

The field strengths of both fields are **<u>vector quantities.</u>**

<u>Fields around a point source are radial.</u>

Differences (any 1):

B1

<u>The gravitational field strength (or force) is related to the (products of the) masses of the objects</u> while the **<u>electric field strength (or force) is related to the (products of the) charges.</u>**

The **<u>gravitational force is only attractive</u>**, but the **<u>electric force can be either attractive or repulsive</u>**.

The **<u>gravitational force acts along the direction of the field lines</u>**, but the **<u>electric force can be either in the direction or opposite to the field line directions</u>**.

(b) An oil drop of mass 1.98×10^{-12} g and a charge of -1.12×10^{-18} C is initially at rest between two parallel vertical plates placed 25.0 cm apart. The plates are connected to an electrical source with an e.m.f. of 2.50 kV as shown in Fig. 5.1.

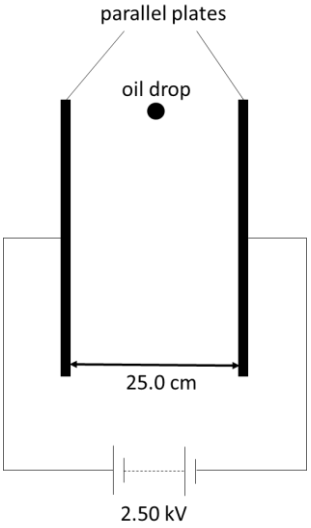


Fig. 5.1

(i) Show that the magnitude of the electric force acting on the oil drop when it is between the plates is 1.12×10^{-14} N.

Solution:

Electric field strength for uniform field, **M1**

$$E = \frac{\text{potential difference between the plates, } V}{\text{spacing between the plates, } d} = \frac{2500}{0.25} = 10000 \text{ V m}^{-1}$$

Electric force acting on oil drop, (taking right as positive),

$F_E = \text{charge of oil drop, } q \times E = (-1.12 \times 10^{-18})(10000) = -1.12 \times 10^{-14} \text{ N (to the left)}$ **M1**

Answer: 1.12×10^{-14} N **A0**

(ii) Hence, determine the magnitude and direction of the initial acceleration of the oil drop.

initial acceleration = …… m s^{-2}

direction = …… **[4]**

Gravitational force acting on the oil drop (taking down as positive)

$F_G = mg = (1.98 \times 10^{-15} \text{ kg})(9.81) = 1.94 \times 10^{-14} \text{ N (downwards)}$ **C1**

Resultant force acting on oil drop,

$F_R = \sqrt{F_E^2 + F_G^2} = \sqrt{(1.12 \times 10^{-14})^2 + (1.94 \times 10^{-14})^2} = 2.24 \times 10^{-14} \text{ N}$ **M1**

$a = \frac{F_R}{m} = \frac{2.24 \times 10^{-14}}{1.98 \times 10^{-15}} = 11.3 \text{ m s}^{-2}$ **A1**

Direction of acceleration = direction of resultant force

$\theta = \tan^{-1}\left(\frac{1.94 \times 10^{-14}}{1.12 \times 10^{-14}}\right) = 60.0° \text{ anti-clockwise from negative x-direction}$ **A1**

(iii) State and explain whether the magnitude and direction of the acceleration obtained in part **(ii)** will remain constant throughout the entire motion of the oil drop as it moves between the plates. **[2]**

Solution:

The two forces on the oil drop, which **are gravitational and electric force remains constant** in both magnitude and direction **M1**

Therefore, by Newton's Second Law, the **acceleration is expected to remain constant** throughout the drops motion between the plates. **A1**

SECTION B (40 marks)

Answer TWO out of THREE questions in Section B.

6 (a) Give three distinguishing characteristics between the *radioactive decay* and the *fission* of a nucleus.

[3]

Solution

Radioactive decay is a **spontaneous** and **random disintegration** of **unstable nucleus**, while fission is a **deliberate process** that is usually triggered by bombarding the nucleus in question with another particle. **B1**

There are **three distinct types of emission** during a radioactive decay (emission of an alpha-particle, a beta-particle or a gamma ray photon) **and one daughter nucleus**, whereas fissions **usually result in emission of neutrons** and two or more daughter nuclei. **B1**

The **products of a fission process are approximately of the same mass**, **this is not usually the case for radioactive decay** **B1**

(b) Plutonium-239 ($^{239}_{94}Pu$) is the plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors.

(i) Part of the plutonium manufacture process involves the most common isotope of uranium, Uranium-238 ($^{238}_{92}U$) absorbing a neutron. Write a nuclear equation that represents this process.

[1]

$$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U$$ **B1**

(ii) The product formed in the process in **(b)(i)** then quickly undergoes two subsequent beta decays to plutonium. An intermediate radioactive isotope X is formed after the first beta decay.

By considering the nuclear equation for this first beta decay, determine the mass and atomic numbers of X. Show your working clearly.

[4]

Solution

As the intermediate radioactive isotope is a result of the beta decay of $^{239}_{92}U$, we need to consider the following nuclear reaction equation

$$^{239}_{92}U \rightarrow {}^{a}_{b}X + {}^{0}_{-1}e$$

M1

where a is the mass number of X
and b is the atomic number of X

balancing the mass and atomic numbers of the equation,

239 = a + 0
a = 239 **M1 A1**

and

92 = b + (-1)
b = 93 **B1**

(iii) Hence, write the nuclear equation representing the second beta decay. **[1]**

Solution

B1

$$^{239}_{93}X \rightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e$$

(iv) A plutonium bomb named "Fat Man" was dropped on Nagasaki on August 9, 1945 ending World War II. At the point of detonation, the following nuclear reaction occurred, incurring a sustained chain reaction process.

$$^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{100}_{42}Mo + {}^{135}_{52}Te + 4{}^{1}_{0}n$$

Fig. 6.1 lists the binding energy (BE) per nucleon of each of the nuclides in this nuclear reaction.

Nuclide	BE per nucleon / MeV
$^{239}_{94}Pu$	7.56
$^{100}_{42}Mo$	8.61
$^{135}_{52}Te$	8.35

Fig. 6.1

It is estimated that 5.88 kg of plutonium in Fat Man was needed to cause the deadly explosion. Determine the energy released if only 17% of the plutonium undergoes nuclear reaction during the explosion.

energy released = …….. J **[5]**

Solution:

Number of fission processes
= 5.88 /(239 u) x 0.17
= 5.88 / (239 x 1.66 x 10^{-27}) x 0.17 **M1**
= 2.52 x 10^{24} **A1**

Energy released in a single fission process
= $BE_{products} - BE_{reactants}$
= $BE_{Mo} + BE_{Te} - BE_{Pu}$ **M1**
= 8.61 (100) + 8.35 (135) – 7.56 (239) **M1**
= 181.41 MeV

Total amount of energy released
= $2.52 \times 10^{24} \times 181.41 \times 10^{6} \times 1.6 \times 10^{-19}$
= 7.31×10^{13} J **A1**

(c) Plutonium-239 is an alpha emitter with a half-life of 24100 years.

(i) Calculate the amount of time for the number of Plutonium-239 isotopes in a sample to reduce by 30%.

amount of time = …….…… years **[3]**

Solution

$$N = N_0 e^{-\lambda t}$$
$$\frac{N}{N_0} = e^{-\lambda t}$$
$$-\lambda t = ln\frac{N}{N_0}$$
$$-\left(\frac{ln2}{t_{1/2}}\right)t = ln\frac{N}{N_0}$$
$$t = -ln\frac{N}{N_0}\left(\frac{t_{1/2}}{ln2}\right) \quad \textbf{M1}$$
$$t = -ln(0.7)\left(\frac{24100}{ln2}\right) = 12400\ years \quad \textbf{M1 A1}$$

(ii) Suggest why plutonium-239 is more dangerous to the body when inhaled as compared to being an external radiation source.

[3]

Solution

As **alpha particles are not very penetrative**, it has a **low chance of getting into the body through human skin**. Therefore, when inhaled, plutonium dust and therefore the **subsequent energetic alpha particles can access the internal body tissues more directly** to cause cancer. **B1 B1 B1**

7 (a) State what is meant by *simple harmonic motion*.

[2]

Simple harmonic motion is defined as the motion of an object whose acceleration *a* is **proportional** to its displacement *x* from a fixed point (equilibrium position) and **B1**
is always **directed towards** that fixed point. **B1**

The defining equation of simple harmonic motion is

$$a = -\omega^2 x$$

(The minus sign indicates that *a* is always in the opposite direction to *x*.)

(b) Describe how, for a simple harmonic motion, the direction of acceleration varies with the direction of the velocity **[2]**

When the object is moving **towards** the equilibrium position, its acceleration and velocity are in the **same** direction. **B1**
When the object is moving **away from** the equilibrium position, its acceleration and velocity are in **opposite** direction. **B1**

(c) A smooth ball of mass *m* is held between two fixed points A and B by means two similar springs, each of spring constant *k*, as shown in Fig. 7.1.

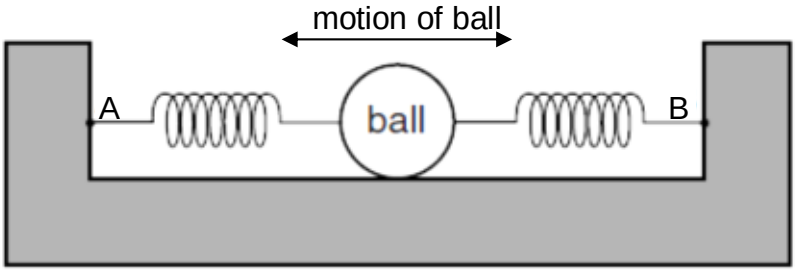


Fig. 7.1

The ball is free to oscillate along the straight line AB on the smooth surface.

When the ball is in equilibrium, the extension of each spring is *e*. The ball 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 ball is given by

$$F = 2kx$$

[2]

forces in springs are $k(e + x)$ and $k(e - x)$ **C1**

resultant = $k(e + x) - k(e - x)$ **M1**

$= 2kx$ **A0**

(ii) The ball is then released. Show that the acceleration *a* of the ball is given by

$$a = -\frac{2kx}{m}$$

[2]

By Newton's Second Law, **B1**

$F_{net} = ma$

$a = -\frac{2kx}{m}$ **A0**

B1

negative sign explained as the acceleration is always oppositely directed to the displacement.

(iii) The mass *m* of the ball is 900 g and the spring constant *k* is 120 N m^{-1}. By comparing the equations of an object executing simple harmonic motion and that in **(c)(ii)**, determine for the ball,

1. the frequency of oscillation,

[3]

$\omega^2 = \frac{2k}{m}$ **C1**

$(2\pi f)^2 = \frac{2\cdot(120)}{0.900}$ **C1**

f = 2.60 Hz **A1**

2. the amplitude if the maximum acceleration of the ball is 5.2 m s^{-2} a

[2]

$\omega^2 x_0 = 5.2$

$x_0 = \frac{5.2}{\frac{2\cdot(120)}{0.900}}$ **C1**

$= 1.95 \times 10^{-2}$ m or 1.95 cm **A1**

3. the maximum kinetic energy of the ball. **[2]**

Max kinetic energy = $\frac{1}{2} m(\omega x_0)^2$ **M1**

$= \frac{1}{2}(0.900)\ \frac{2\cdot(120)}{0.900}(0.0195)^2$

= 0.0456 J **A1**

(iv) A student investigates the variation in the kinetic energy, *E*, of the oscillating ball as shown in Fig. 7.2.

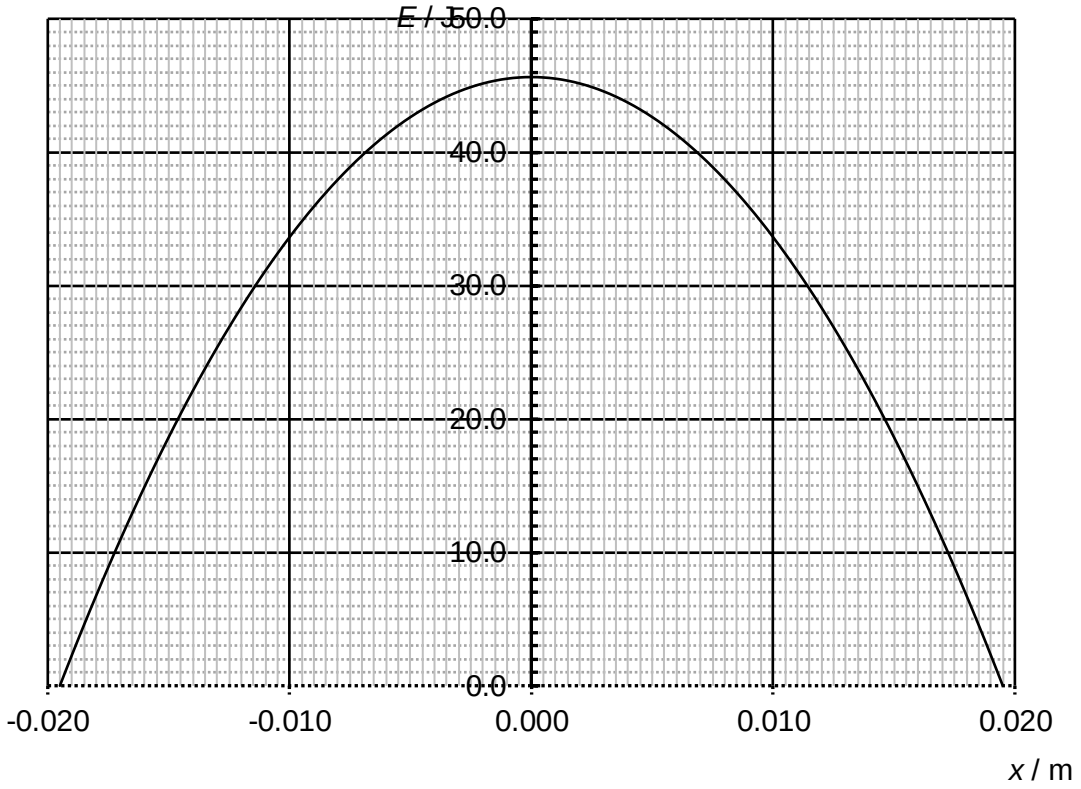


Fig 7.2

The student repeats the investigation but with a smaller amplitude. The maximum value of *E* is now found to be 15 mJ.

Use Fig. 7.2 to determine the change in the amplitude. Explain your working.

change in the amplitude = …….. m **[3]**

either change in energy = 30.6 mJ **C1**

then obtain answer from graph with a shift of the KE graph to read off a value of approximately 0.011± 0.0005 m **C1**

Change in amplitude = 0.0195 – 0.0110 = 0.0085 m **A1**

or max E proportional to (amplitude)^2 **OR**

So $\frac{(KE_{max})_1}{(KE_{max})_2} = \left(\frac{0.0195}{x}\right)^2$ **C1**

new amplitude, x = 0.0112 m **C1**

Change in amplitude = 0.0195 – 0.0112 = 0.0083 m **A1**

(d) The experiment was repeated with a rough ball instead. Suggest and explain the effect it would have on the ball's oscillatory motion. **[2]**

There will now be damping and its **amplitude will gradually decrease** **B1**

while **its period would increase** **B1**

8 (a) A rectangular coil is rotating about an axis between two magnets with uniform angular velocity ω due to the action of an external applied force. The uniform magnetic field B between the two magnets is 0.90 T. The coil is rotating at 40 revolutions per second. The number of turns N of the coil is 40. The cross-sectional area A of the coil is 3.0 m^2. A current is found going through the resistor R of resistance 30 Ω. Fig. 8.1 shows the instant when the plane of the coil is in a horizontal position.

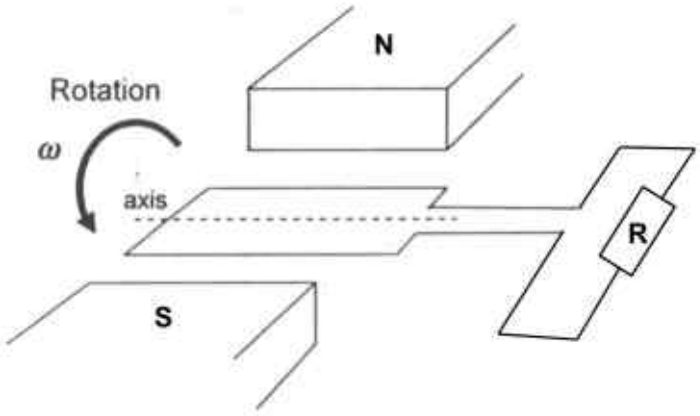


Fig. 8.1

(i) Explain how the current flowing through the resistor R is formed. **[3]**

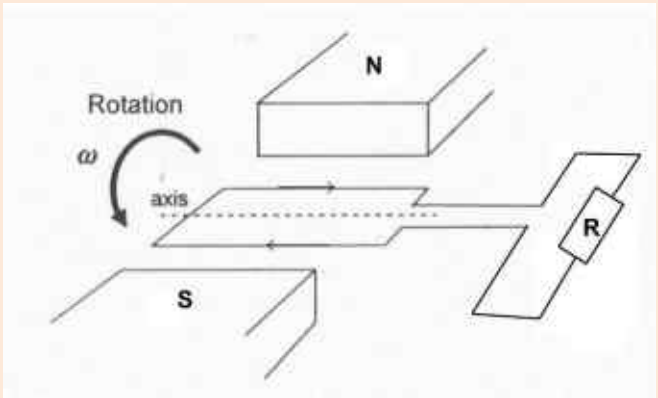
Solution:

As the coil rotates, there is a continuous **change in effective area of the coil exposed to the magnetic field**. Therefore, there is a **changing magnetic flux linkage**. By **Faraday's Law, an e.m.f. will be induced**. **B1** **B1**

Since the **circuit is closed**, induced current will flow through resistor R. **B1**

(ii) On Fig. 8.1, indicate the direction of flow of current and explain your reasoning. **[3]**

Solution:



B1

[direction of current must be correct] **B1**

As the coil rotates, the area exposed to the external magnetic field increases. Hence magnetic flux linkage increases. By **Lenz's law** and using the **right hand grip rule,** **B1**

induced current will flow in such a way so as to **produce a magnetic field to restore the magnetic flux linkage to the original state**.

(iii) The coil starts rotating when it is in the position shown in Fig. 8.1.

1. Determine the period of the rotation of the coil

period = …….. s **[2]**

Solution:

M1

Angular velocity, ω = 2πf = 2π(40) = 80π

ω = $\frac{2\pi}{T} = 80\pi$ **A1**

T = 0.025 s

2. Determine the maximum current flowing through the coil during the rotation.

maximum current = …….. A **[2]**

Solution:

Magnetic flix linkage, Φ = NBA sin ωt (since at t = 0 s, Φ = 0 Wb)
= (40)(0.9)(3) sin (80πt)
= 108 sin (80πt)

Induced e.m.f., E = $-\frac{d\phi}{dt}$

$= -\frac{d[108\sin(80\pi t)]}{dt}$

= - 108π(80) cos (80πt)
= - 8640 π cos (80πt) **M1**

Maximum E = 8640 π V

Max current = $-\frac{8640\pi}{30} = 905\text{A}$ **A1**

3. Sketch a graph on Fig. 8.2 showing the variation with time of current through the resistor. Show the values of period and peak current on the graph.



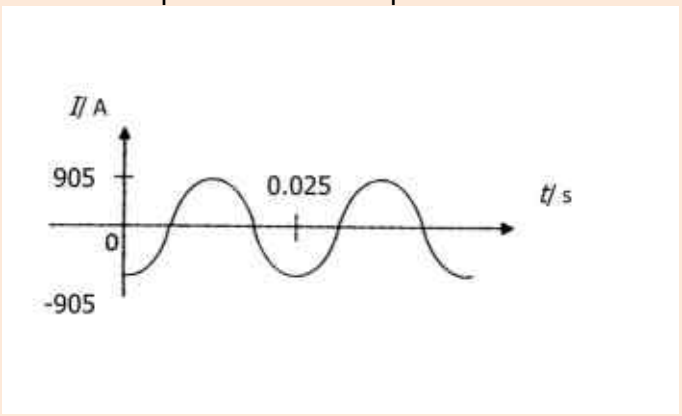
[2]

Fig. 8.2

Solution:

B1 mark for shape of graph (-cos) **B1**

B1 mark for correct value of peak current and period **B1**



(iv) Determine the mean power through the resistor.

mean power = ... W **[3]**

Solution:

$$I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{905}{\sqrt{2}} = 640\ A$$ **M1**

$$P_{mean} = I_{rms}{}^2 R = 640^2\ (30)$$ **M1**

$$= 1.23 \times 10^7\ W$$ **A1**

(b) The primary coil of a transformer has 1500 turns and is connected via cables to a 250 $V_{r.m.s.}$ supply. The secondary coil has 50 turns and is connected, through a switch and a diode, to a 10.0 V rechargeable battery, as illustrated in Fig. 8.3.

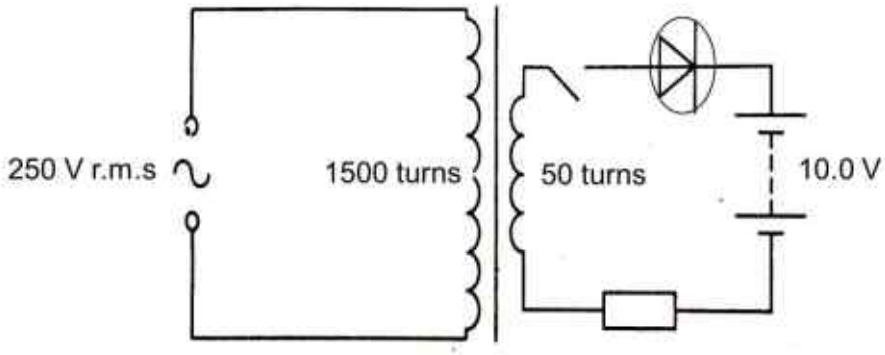


Fig. 8.3

(i) Initially, the switch is open. Considering both the transformer and the diode to be ideal, calculate the r.m.s. potential difference across the secondary coil.

$V_{r.m.s}$ = ... V **[2]**

Solution:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{V_s}{250} = \frac{50}{1500}$$ **M1**

$$V_s = 8.3\,V$$ **A1**

(ii) The switch is now closed to recharge the battery.

1. Suggest why the diode is necessary in the secondary circuit.

[2]

Solution:

The battery can only be charged with a DC with the **current going into the positive terminal**. (If current comes out from the positive terminal, the battery will discharge.) **B1**

The diode **rectifies the AC to DC** for charging the battery. **B1**

2. Suggest why the resistor is necessary in the secondary circuit.

[1]

Solution:

The resistor is connected in series to **prevent a large current** which may damage the battery. **B1**

HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**15S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9646/01

Paper 1 Multiple Choice

22 September 2016

1 hour 15 minutes

Additional Materials: Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

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 **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 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.

Data

speed of light in vacuum,
$c = 3.00 \times 10^{8}$ 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 Avogrado 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, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$

$v = \pm\omega\sqrt{x_o^2 - x^2}$

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, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 Which of the following is **not** a unit of energy?

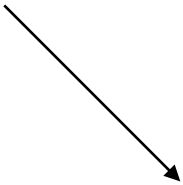
A W s **B** N m **C** kW h **D** N s^{-1}

2 The initial velocity of an object is shown by the vector ***u***. The final velocity of the object is shown by the vector ***v***.

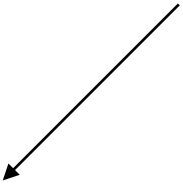


Which arrow shows the change in velocity of the object?

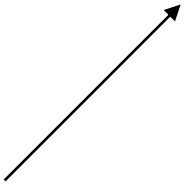
A



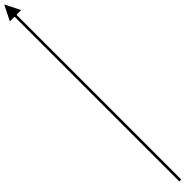
B



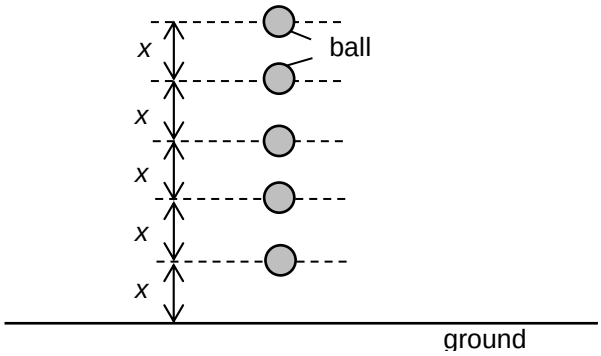
C



D



3 Five balls are arranged equidistance from each other as shown below.



The five balls are dropped at the same time. The balls should hit the ground at

A the same time

B equal time intervals

C decreasing time intervals

D increasing time intervals

4 A tennis ball is served 2.5 m above ground at an angle of 5° above the horizontal direction with an initial speed of 30 m s^{-1}. After how long does the ball hit the ground?

A 0.3 s **B** 0.6 s **C** 1.0 s **D** 1.9 s

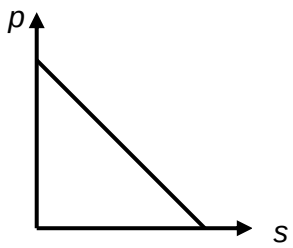
5 A parachutist jumps out of an aeroplane and undergoes constant acceleration to reach a velocity of 58.8 m s^{-1} in 6.00 s. She then pulls the parachute cord and after a 4.00 s constant deceleration, descends at 10.0 m s^{-1} for 60.0 s before reaching the ground. From what height did the parachutist jump?

A 814 m **B** 914 m **C** 894 m **D** 952 m

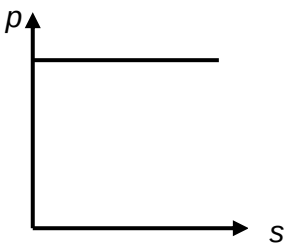
6 A railway carriage is travelling at a constant speed along a straight horizontal track. The brakes are then applied, which result in a constant force opposing the carriage's motion. Other forms of friction such as air resistance can be neglected.

Which of the graphs below best represents the variation of the momentum *p* with distance travelled *s*, taken from the moment the brakes are first applied?

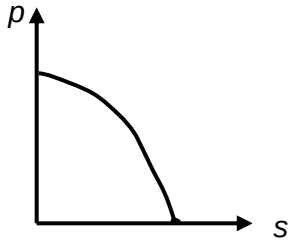
A



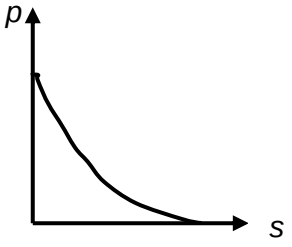
B



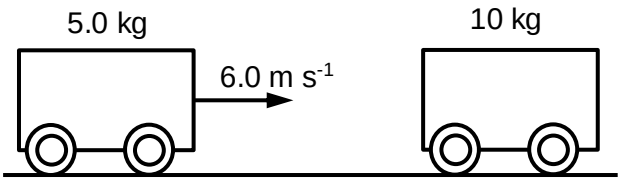
C



D



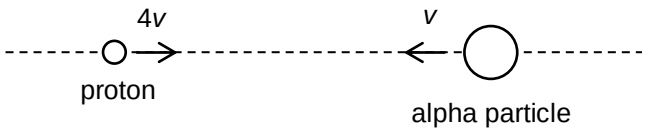
7 A trolley of mass 5.0 kg travelling at a speed of 6.0 m s^{-1} collides head-on and locks together with another trolley of mass 10 kg which is initially at rest. The collision lasts for 0.20 s.



What is the total kinetic energy of the two trolleys after the collision and the average force acting on each trolley during this collision?

	Total kinetic energy after the collision / J	Average force on each trolley / N
A	30	150
B	75	150
C	30	100
D	75	100

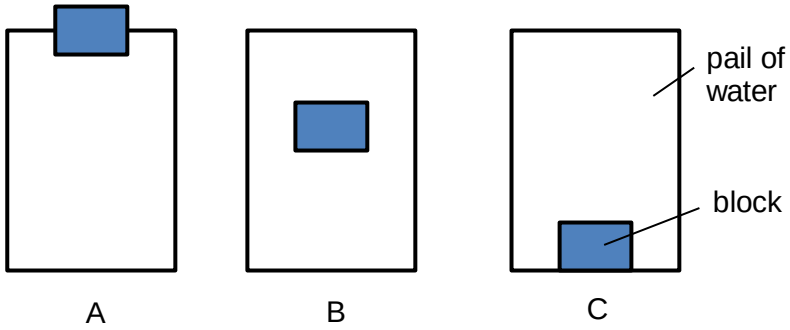
8 A proton travelling at speed 4*v* and an alpha particle at a speed *v* undergo a head-on, elastic collision.



After the collision, what are the speeds of the two particles?

	Speed of the alpha particle	Speed of the proton
A	0	0
B	0.6*v*	2.4*v*
C	*v*	4*v*
D	4*v*	*v*

9 Three identical pails of water are filled to the brim. Three blocks of the same volume but made of different materials are placed into the pails. The figure below shows the final position of the three blocks. The block in pail A floats, the block in pail B is fully submerged, while the block in pail C rests on the pail's bottom.



When the three pails are placed on a weighing scale, how do the three weights (water and pail and block combined) compare?

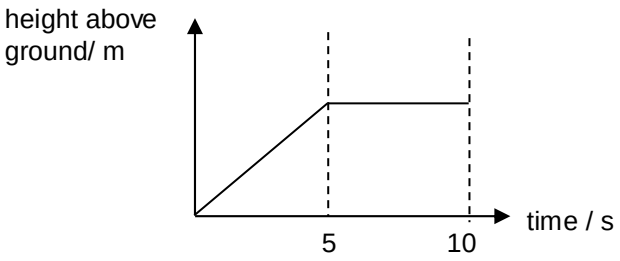
A Weight of A < Weight of B < Weight of C

B Weight of A < Weight of B = Weight of C

C Weight of A = Weight of B = Weight of C

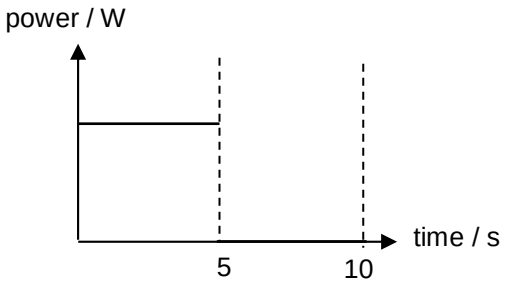
D Weight of A = Weight of B < Weight of C

10 A crane lifts a load at constant speed vertically for the first five seconds. It then holds it at a fixed height for another five seconds. The variation of the height of the load above the ground is shown in the graph below.

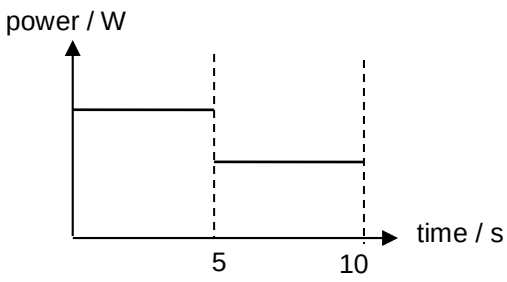


Which of the following graphs shows the variation of power supplied to the load with time?

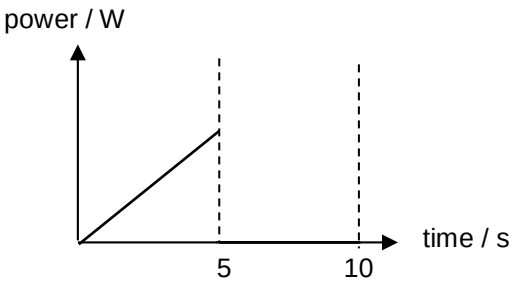
A



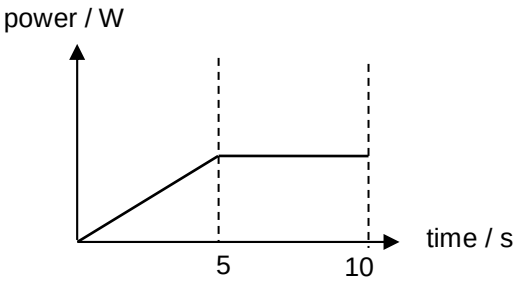
B



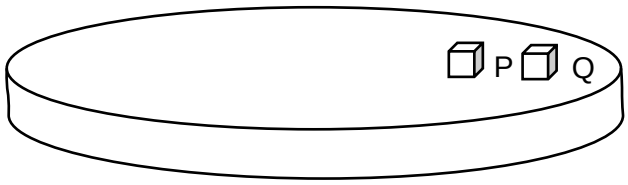
C



D



11 Two identical objects rest on a flat rough circular disc.



The disc starts from rest and starts spinning about its central axis with increasing rate. When the disc spins at a certain rate, one of the objects slides off the disc.

Which of the following statements is correct?

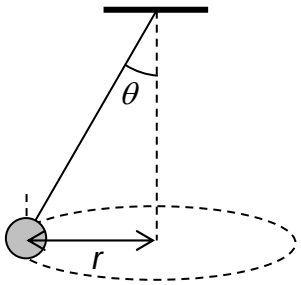
A The friction experienced by P and Q are always equal.

B P experiences larger friction than Q.

C Q will start to slide first due to larger angular velocity.

D Q will start to slide first due to larger radius.

12 A metal bob is suspended with a light inextensible cord from the ceiling. It is set to whirl in a horizontal circle of radius r with a constant speed such that the cord is inclined at an angle θ to the vertical as shown in the diagram.



Determine the period of rotation for the metal bob.

A $\sqrt{\dfrac{4\pi^2 r}{g}}$

B $\sqrt{\dfrac{4\pi^2 r}{g\sin\theta}}$

C $\sqrt{\dfrac{4\pi^2 r}{g\tan\theta}}$

D $\sqrt{\dfrac{4\pi^2}{rg\tan\theta}}$

13 Two satellites are orbiting the Earth in two different circular orbits. Satellite X orbits on the equatorial plane while satellite Y orbits on a plane perpendicular to satellite X. The orbital radius of satellite X is four times that of satellite Y.

Which of the following statement is correct?

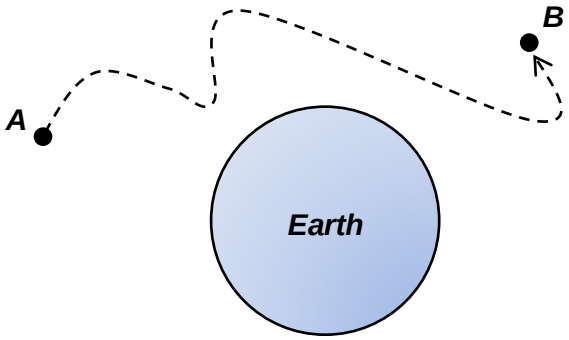
A The torque on satellite Y is stronger than that on satellite X.

B Satellite Y is travelling at twice the speed of satellite X.

C The gravitational force on satellite Y is four times that of satellite X.

D The gravitational potential energy of satellite Y is higher than that of satellite X.

14 A spacecraft travels from location *A* to location *B* in the Earth's gravitational field along the path shown.



The work done by gravitational force on the spacecraft along the given path is equal to

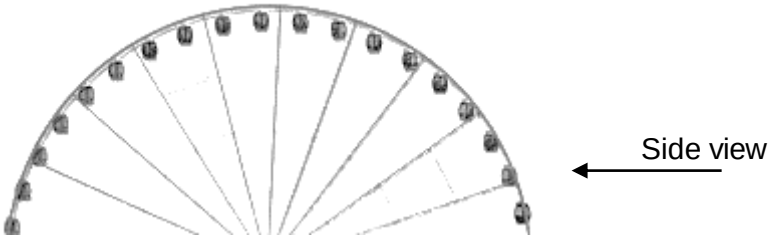
A the change in gravitational potential energy between *A* and *B*.

B the change in kinetic energy between *A* and *B*.

C the change in total mechanical energy between *A* and *B*.

D zero.

15 A lady is able to see the side view of a Ferris wheel from her kitchen window. However, half of her view is blocked by some vegetation. This Ferris wheel is turning in such a way that she can see the individual capsules appearing out of the vegetation, reaching up vertically to the top and then disappearing out of her view.



Front view

Which of the option best describes the motion of each capsule as it appears out of the vegetation to the highest point according to this lady?

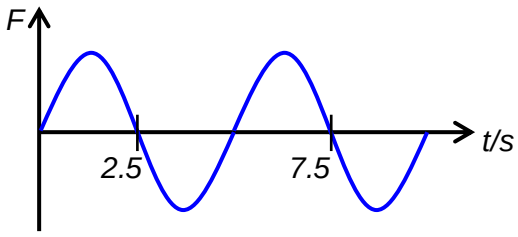
A It rises up with decreasing speed.

B It rises up with increasing speed.

C It rises up with decreasing then increasing speed.

D It rises up with increasing then decreasing speed.

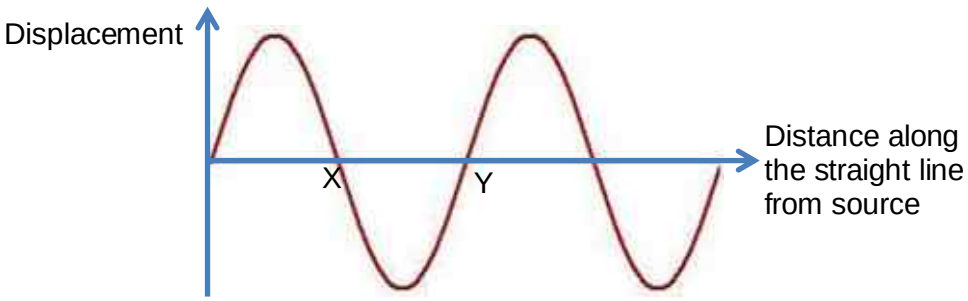
16 An oscillating system has a natural frequency of 0.25 Hz. It is subjected to a periodic driving force *F* as shown.



What is the frequency that the system would oscillate at?

A 0.20 Hz **B** 0.25 Hz **C** 1.00 Hz **D** 5.00 Hz

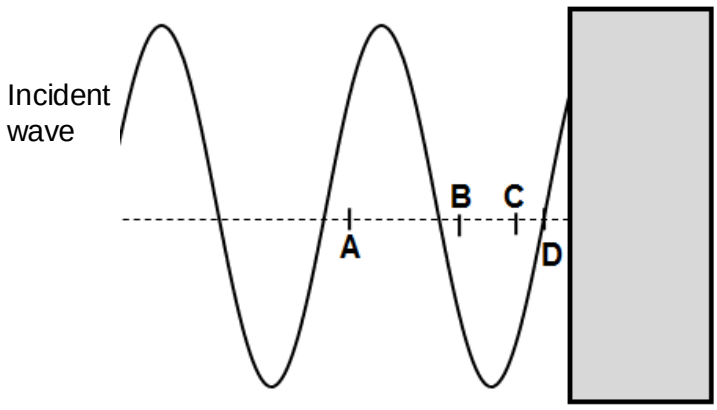
17 As a sound wave passes through a region of space, the displacement of the air molecules along a straight line is plotted as shown below.



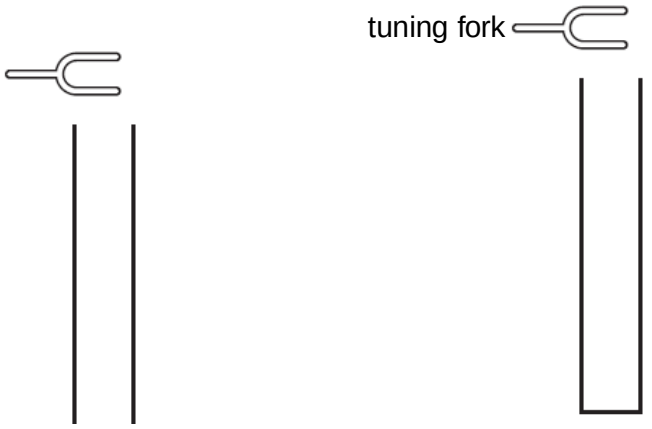
Which of the following correctly describes the sound wave at locations X and Y?

	X	Y
A	Compression	Compression
B	Compression	Rarefaction
C	Rarefaction	Compression
D	Rarefaction	Rarefaction

18 Stationary water waves are set up in a water tank. The diagram shows the wave profile of a wave traveling towards the side of the water tank. This wave overlaps with the reflected wave that travels away from the side of the water tank. Which labeled position is the location of a node of the stationary wave nearest to the side of the water tank?



19 Two identical tuning forks are placed above a resonance tube open at both ends of length L_1 (Fig. (a)) and a resonance tube closed at one end of length L_2 (Fig. (b)). In both cases, resonance is observed.



(a) (b)

Which of the following expressions, where m and n are positive integers, give the ratio of $\frac{L_2}{L_1}$?

A $\frac{2m-1}{2n}$

B $\frac{2m-1}{4}$

C $\frac{2}{m}$

D 1

20 The thermodynamic temperature scale is considered more fundamental than the Centigrade temperature scale because

A it is determined using the triple point of water instead of ice point, which is more reproducible.

B it is independent of the properties of materials.

C it can measure a greater range of temperatures.

D it is related to the random kinetic energy of the particles.

21 The piston of a gas-tight syringe containing an ideal gas is pulled outwards quickly. Which of the following changes is **incorrect**?

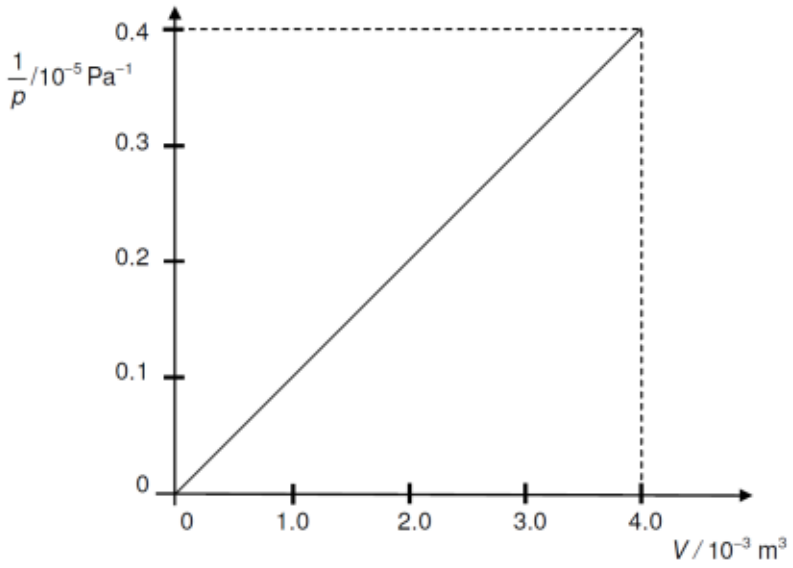
A The density of the ideal gas decreases.

B The pressure of the ideal gas decreases.

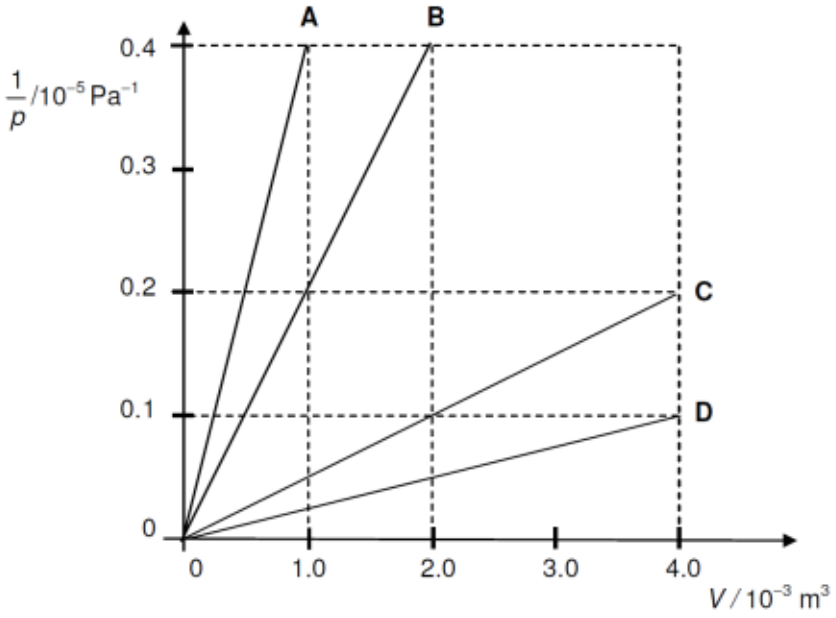
C The temperature of the ideal gas decreases.

D The root-mean-square speed of the ideal gas increases.

22 The figure below shows the variation of *1/P* with *V* for n moles of an ideal gas, where *P* and *V* respectively represent the pressure and volume of the gas.



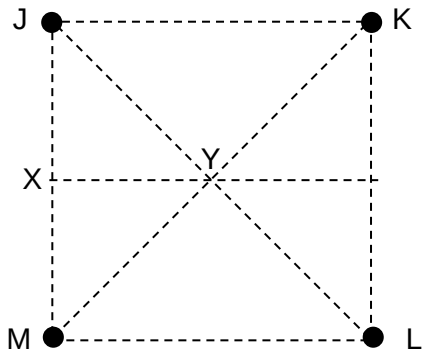
If the number of moles of the gas is increased to 4n and the thermodynamic temperature is halved, which graph will be obtained?



23 Starting from rest, a proton and an alpha particle are accelerated through potential differences of *V* and 2*V* respectively. If the final momentum of the proton is *p*, determine the final momentum of the alpha particle.

A *p** **B** 2*p** **C** 4*p** **D** 16*p*

24 Four point charges are at the corners of a square JKLM. The point charges J and K are negatively charged but the point charges L and M are positively charged. The magnitude of the charges are the same. An electron is brought from point X to point Y in a straight line by an external force without any change in its speed.



Which of the following is correct about the change in electric potential energy of the system and work done by the external force?

	change in electric potential energy	work done by the external force
A	yes	yes
B	yes	no
C	no	yes
D	no	no

25 Why does the current increase when the potential difference applied across a resistor is increased?

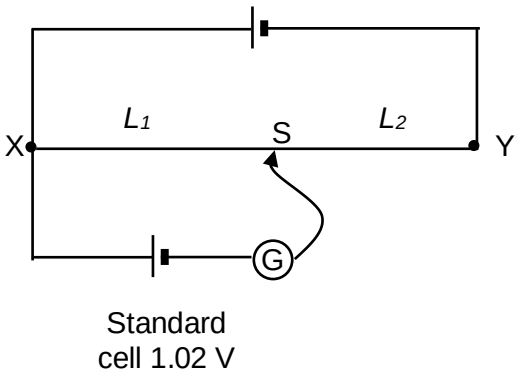
A The rise in temperature increases the thermal motion of the charge carriers.

B The mean time between collision increases

C The acceleration of the charge carriers between collision increases.

D More charge carriers are released.

26 A standard cell of e.m.f. 1.02 V is connected in a potentiometer as shown in the figure below. It is found that there is no current through the galvanometer when the sliding contact is at S, L_1 from X and L_2 from Y.



What is the potential difference between XY?

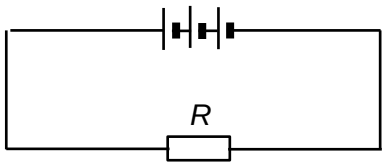
A $1.02\left(\frac{L_2}{L_1}\right)V$

B $1.02\left(\frac{L_1}{L_2}\right)V$

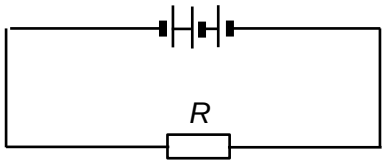
C $1.02\left(\frac{L_1+L_2}{L_1}\right)V$

D $1.02\left(\frac{L_1}{L_2+L_2}\right)V$

27 Three identical cells each having an e.m.f. of 1.5 V and a constant internal resistance of 2.0 Ω are connected in series with a 4.0 Ω resistor *R*, firstly as in circuit (i), and secondly as in circuit (ii).



Circuit (i)



Circuit (ii)

What is the ratio $\frac{\text{power in R in circuit (i)}}{\text{power in R in circuit (ii)}}$?

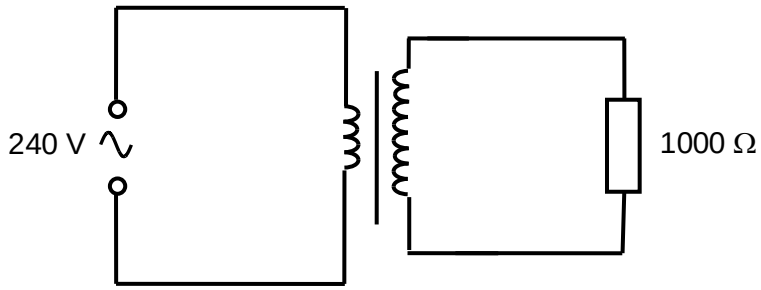
A 9.0 **B** 7.2 **C** 5.4 **D** 3.0

28 An alternating current, *I*/*A*, varies with time, *t*/*s* according to the equation $I = 5\sin\left(\sqrt{3}\,t\right)$.

What is the mean power developed by the current in a resistive load of 10 Ω?

A 125 W **B** 250 W **C** 375 W **D** 750 W

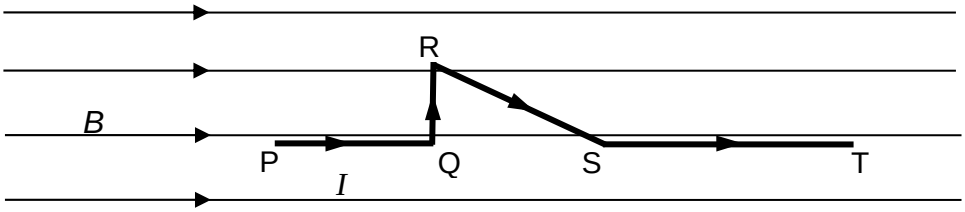
29 An ideal transformer is used to step-up a 240 V a.c. power supply. The output is used to heat a 1000 Ω resistive load. The ratio of the primary turns to secondary turns is 1:5.



What is the current in the primary coil?

A 0.24 A **B** 1.2 A **C** 6.0 A **D** 36.0 A

30 A bent wire PQRST carrying a current I is placed in a magnetic field of flux density B as shown. PQ is shorter than ST. PQ and ST is on the same horizontal line in the direction of the magnetic field.



Using the notation F_{xy} to represent the magnitude of the force experienced by a segment XY of the wire due to the magnetic field, which of the following is true?

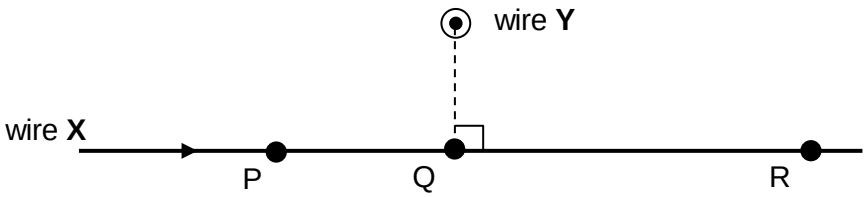
A $F_{QR} = F_{RS}$ and $F_{PQ} < F_{ST}$

B $F_{QR} = F_{RS}$ and $F_{PQ} = F_{ST}$

C $F_{QR} < F_{RS}$ and $F_{PQ} < F_{ST}$

D $F_{QR} < F_{RS}$ and $F_{PQ} = F_{ST}$

31 Two long straight current-carrying wires, X and Y, are placed perpendicular to each other as shown in the diagram. Current flows from left to right in wire X and out of the page in wire Y. P, Q and R are 3 points on wire X.



Which of the following statements is true?

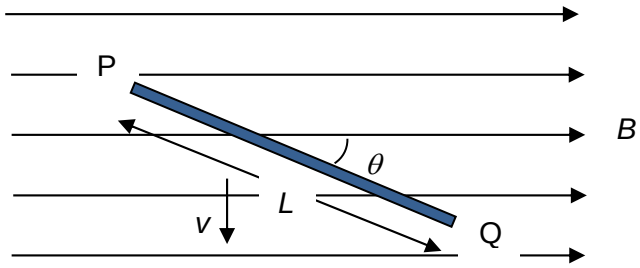
A The magnetic force at point P acts in the opposite direction to that at point R.

B The magnitude of the magnetic force at point R is smallest among all three points.

C The magnitude of the magnetic force at point Q is the largest among all three points.

D There is no magnetic force acting on wire X at all three points, P, Q and R, as the two wires are placed perpendicular to each other.

32 A thin metallic rod PQ with length *L* is released in a uniform and horizontal magnetic field *B*. It is accelerating vertically downwards with a velocity *v*. Its length is at an angle of θ to the horizontal as shown. Its velocity, its length and the magnetic field are all in the same plane.

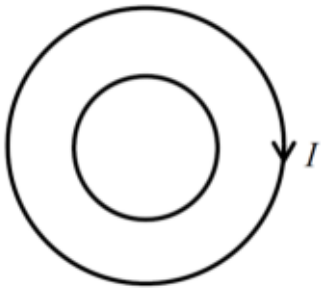


side view

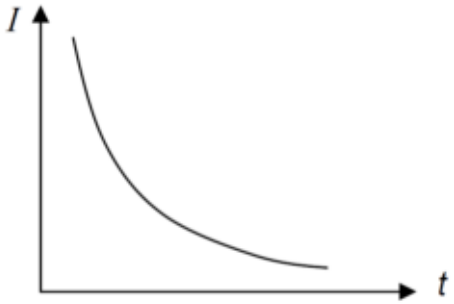
What is the magnitude of the induced e.m.f. between the ends of this rod?

A 0 **B** BLv **C** $BLv\cos\theta$ **D** $BLv\sin\theta$

33 Two separate circular wire loops are concentric and lie in the same plane as shown.



The current in the outer loop is clockwise and decreasing with time as shown in this graph:



The induced current in the inner loop is

A decreasing in the clockwise direction.

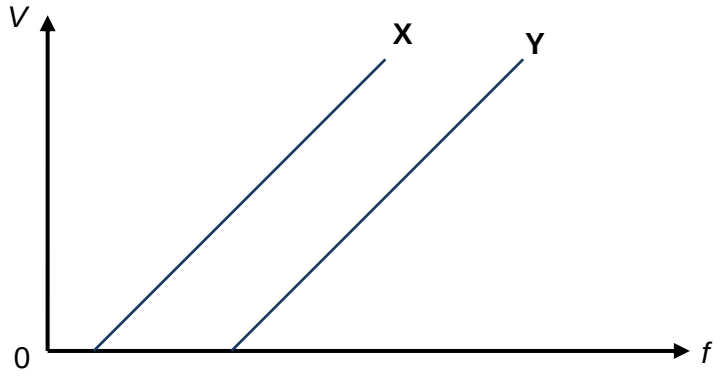
B decreasing in the anti-clockwise direction.

C increasing in the clockwise direction.

D increasing in the anti-clockwise direction.

34 In a photoelectric effect experiment, electrons are ejected from metals X and Y by light of frequency *f*. The potential difference *V* required to stop the electrons is measured for various frequencies.

The figure below shows the results of the experiment for both the metals.



Which of the following statements can be correctly deduced from the the graph?

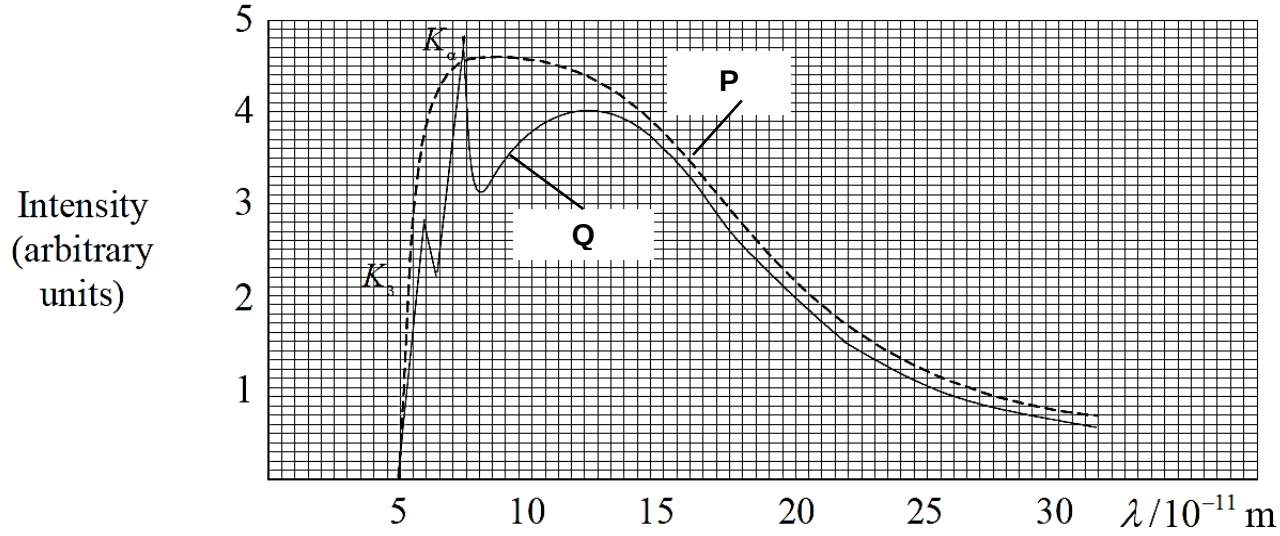
A When light of the same frequency is shone on each metal, the maximum kinetic energy of the photoelectrons from metal X is smaller than the maximum kinetic energy of the photoelectrons from metal Y.

B The intensity of the light shining on metal X is larger than the intensity of the light shining on metal Y.

C The threshold wavelength metal X is larger than the threshold wavelength of metal Y.

D The work function of metal X is larger than the work function of metal Y.

35 The graph below shows the X-ray spectra produced by the two tubes that uses P and Q as the target material.



Which of the following statement is **incorrect**?

A The maximum frequency of the X-ray produced by both tubes is 6×10^{18} Hz.

B The accelerating potential used for both tubes is 25 kV.

C Targets P and Q are made of different elements.

D The difference in the energy levels between the K-shell and L-shell for Q is 3.3×10^{-15} J.

36 In an experiment to learn more about the structure of the atom, Geiger and Marsden fired alpha particles at a thin sheet of gold foil.

What conclusion can be drawn from the results of the experiment?

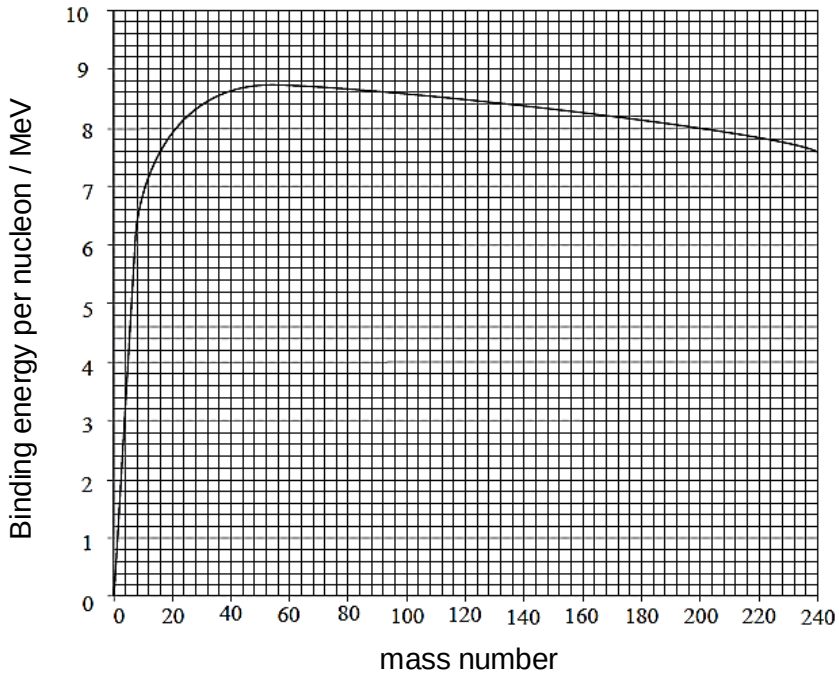
A Neutrons and protons are significantly more massive than electrons.

B The atomic nucleus occupies a very small fraction of the volume of an atom.

C Electrons orbit the atomic nucleus.

D The nucleus contains the protons and neutrons.

37 The figure shows a graph of the binding energy per nucleon for a number of naturally-occurring nuclides plotted against their mass number.



A $^{235}_{92}U$ nucleus fission produces two fission products of approximately equal nucleon number. Which value is the best estimate of the energy released from the fission of one $^{235}_{92}U$ nucleus?

A 1 MeV **B** 8 MeV **C** 200 MeV **D** 1 800 MeV

38 A sample of radioactive isotope $^{A}_{Z}X$ has a half life of τ.

Given that the activity of a pure sample of this radioactive nuclei is R, and Avogadro constant is L, what is the mass of this sample in grams (g)?

A $\frac{RA\tau}{L\ln 2}$ **B** $\frac{AL\ln 2}{R\tau}$ **C** $\frac{RZ\tau}{L\ln 2}$ **D** $\frac{ZL\ln 2}{R\tau}$

39 Which of the following statements about laser is **false**?

A When a laser beam passes through a small aperture, it undergoes diffraction.

B The optical resonator helps to ensure the laser beam is unidirectional.

C Excitation of atoms in the lasing medium can only be done by stimulated absorption.

D Most of the photons in the laser beam is created through stimulated emissions.

40 Which of the following statements below on intrinsic semiconductors is **true**?

A There are more electrons in the conduction band than there are holes in the valence band at room temperature.

B There are equal number of electrons in the valence band and holes in the conduction band at room temperature.

C The total current flow is the sum of both 'hole' and 'electron' currents.

D The valence band is completely filled and the conduction band is completely empty at room temperature.

End of Paper

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**15S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9646/02

Paper 2 Structured Question

13 September 2016

1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly 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, paperclips, highlighters, glue or correction fluid.

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		
1		8
2		7
3		9
4		11
5		10
6		15
7		12
Deductions		
Total		72

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, $\phi = -\frac{Gm}{r}$

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, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** A tennis ball is thrown vertically downwards and bounces on the ground. The ball leaves the hand with an initial speed of 1.5 m s^{-1} and at a height of 0.65 m above the ground. The ball rebounds and is caught when it is travelling upwards with a speed of 1.0 m s^{-1}.

Assume that air resistance is negligible.

(i) Calculate the speed of the ball just before it strikes the ground.

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

(ii) The ball is released at $t = 0$. It hits the ground at t_1 and is caught at time t_2. On Fig 1.1, sketch the velocity-time graph for the vertical motion of the tennis ball from the time it leaves the hand to when it returns. Assume that the contact time between the ball and the ground is negligible. The initial velocity **X** and final velocity **Y** are marked on Fig 1.1.

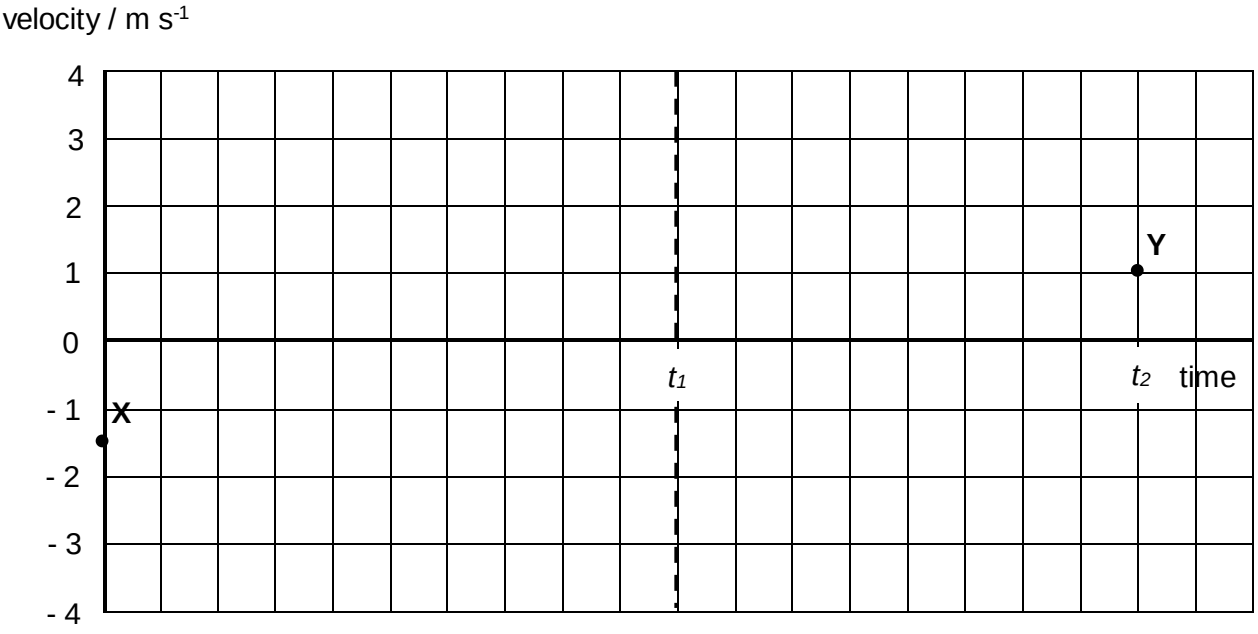


Fig. 1.1 [3]

(iii) Explain if the bounce is elastic.

.....

.....

..... [2]

(b) Sketch on Fig 1.1, the velocity-time graph of the tennis ball if air resistance is not negligible. Label this graph as **P**. [1]

2 Fig. 2.1 shows an asteroid of mass 1.8 x 10^{18} kg, heading towards the surface S of a planet. H represents a point in the asteroid's trajectory, a distance 5.0 x 10^{7} m from the centre of the planet.

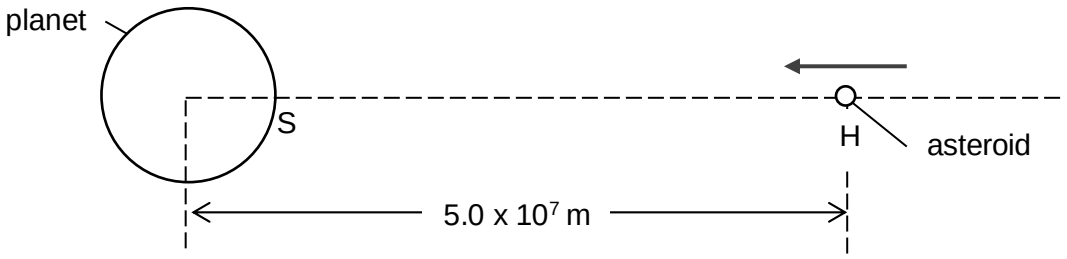


Fig. 2.1

(a) Given that planet has a mass of 7.0 x 10^{24} kg and a radius of 6.0 x 10^{6} m, determine the change in gravitational potential energy of the system as the asteroid moves from H to S.

change in gravitational potential energy = ... J [2]

(b) The graph in Fig. 2.2 shows how the gravitational force *F* acting on the asteroid varies with distance *r* measured from the center of a planet.

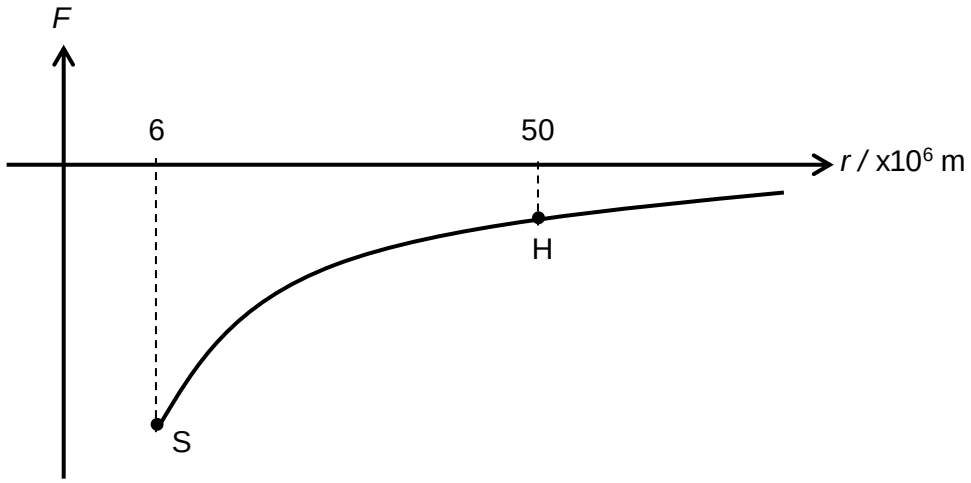


Fig. 2.2

(i) State how the change in gravitational potential energy of the system calculated in **(a)** is represented in the graph.

.....

[1]

(ii) Describe and explain the motion of the asteroid as it travels from H to the surface S of the planet.

.....

.....

.....

.....

[2]

(iii) Will the graph in Fig. 2.2 change if the rotation of the planet is taken into account? Explain your answer clearly.

.....

.....

.....

.....

[2]

3 **(a)** State *Hooke's Law*.

.....

.....

..... [1]

(b) Two small identical spheres, each of mass m are connected to each other via a light spring of spring constant k. The assembly is placed on a smooth horizontal table as shown in Fig. 3.1.

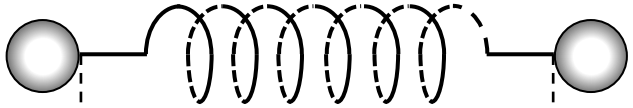


Fig. 3.1

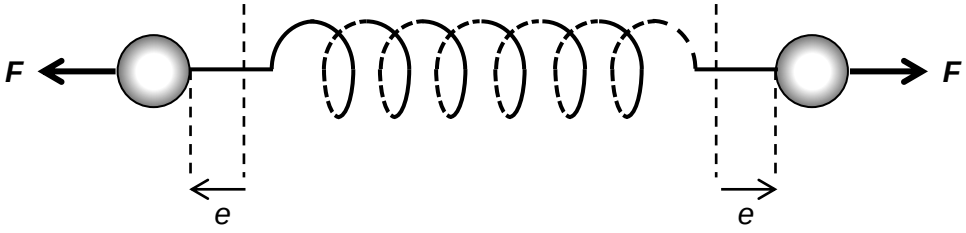


Fig. 3.2

A person stretches the spring slowly by pulling the two spheres away from each other. When the separation between them increases by an amount $2e$, he stops. The force he exerts on each sphere is F (Fig. 3.2).

(i) Write down an expression for F.

[1]

(ii) Show that the elastic potential energy stored in the spring is given by $U = 2ke^2$.

[1]

(iii) The spheres are then released from rest and allowed to move towards each other.

Determine the maximum speed v_o attained by each sphere, given that the spring constant of the spring is 15 N m^{-1}, the initial extension e on each side of the spring is 2.5 cm and the mass of each sphere is 50 g.

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

(iv) The system is found to subsequently oscillate with an angular frequency ω.

Using the value found in **(b)(iii),** determine the angular frequency of the oscillation.

angular frequency = ... [3]

(v) This system of two spheres connected via a light spring is used to model the vibration of diatomic molecules. Suggest one area in which this model may not be appropriate in this modelling.

.....

.....

.....

..... [1]

4 Fig. 4.1 illustrates two large, parallel metal plates G and H, a distance 12.0 cm apart in vacuum, with G at a potential of +6.0 V and H at -6.0 V. ST is a line perpendicular to the plates.

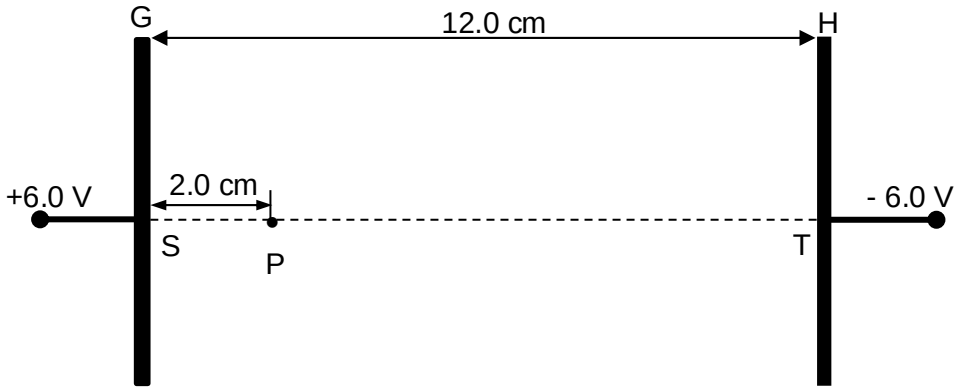


Fig. 4.1

(a) Write down the general equation, showing the relationship between the electric field strength *E* at any point and its electric potential *V*.

[1]

(b) P is a point 2.0 cm from plate G along ST. (Fig. 4.1). Determine the magnitude of the electric field strength at P.

electric field strength = ... N C^{-1} [2]

(c) An uncharged metal plate Z of thickness 3.0 cm is now inserted midway between the two large plates where its surface is parallel to the surfaces of the two plates as shown in Fig.4.2.

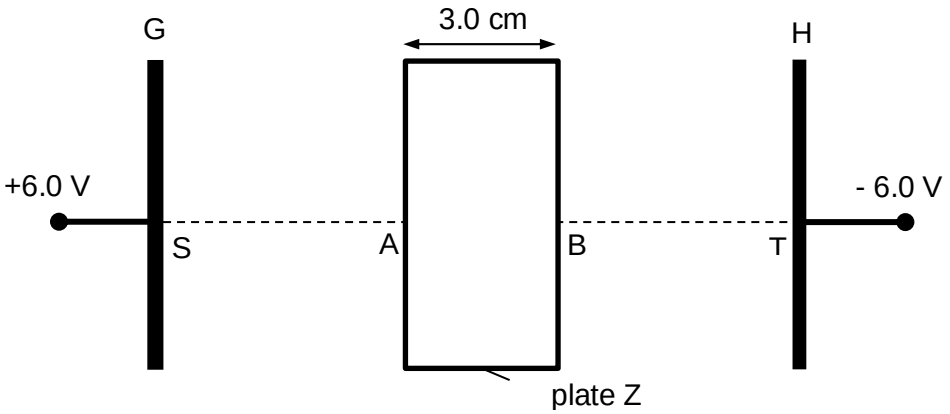


Fig. 4.2

(i) Sketch in Fig. 4.2 the distribution of charges in the metal plate Z. [2]

(ii) Sketch in Fig. 4.3, labelled graphs to show the variation with distance x from S to T of the

1. electric potential V and

2. electric field strength E. [4]

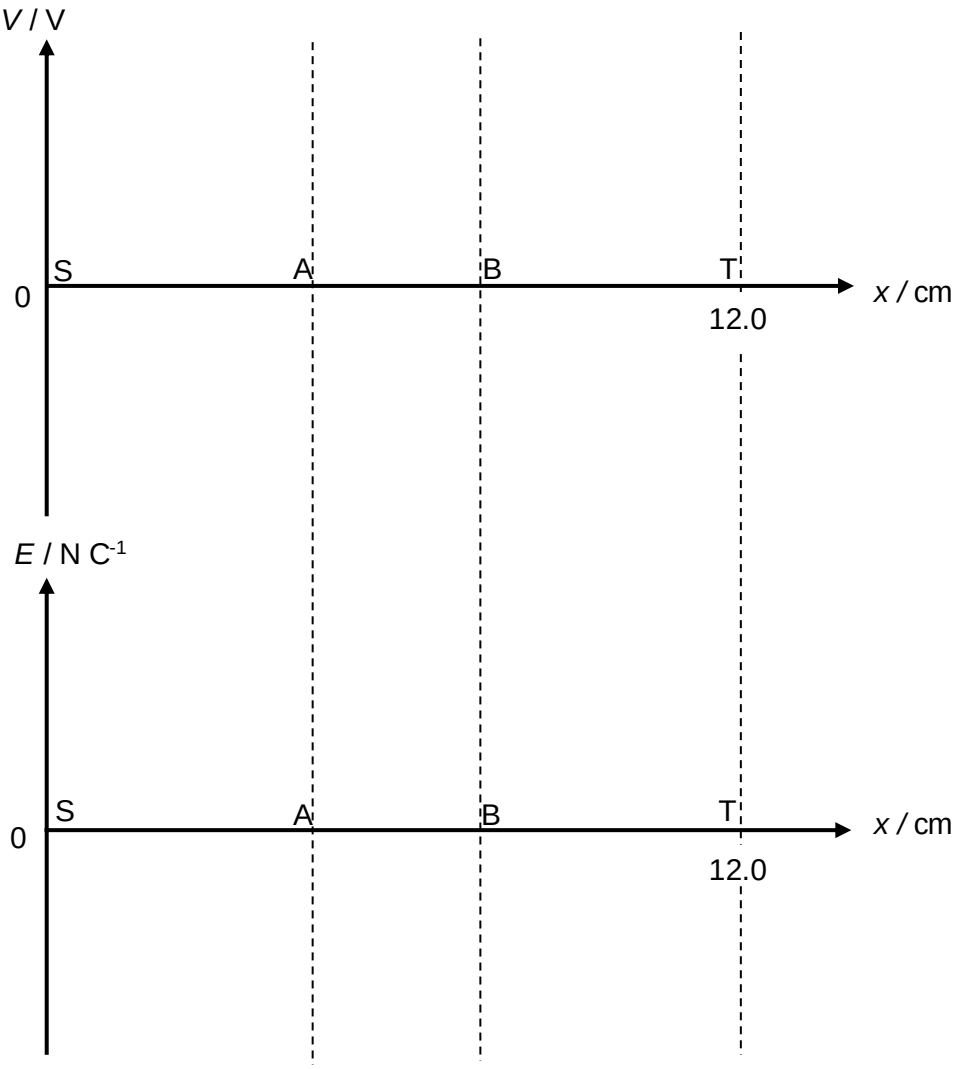


Fig. 4.3

(iii) An external force is applied to slowly move the metal plate Z to infinity. Describe and explain the change in the electric potential energy of the system.

.....

.....

.....

.....

..... [2]

5 A long molecule in a purple food dye can absorb light. When photons are absorbed by the dye molecule, one of its electrons jumps from the lowest energy state E_0 to a higher excited state. The energy levels for the electrons to jump are shown in Fig. 5.1.

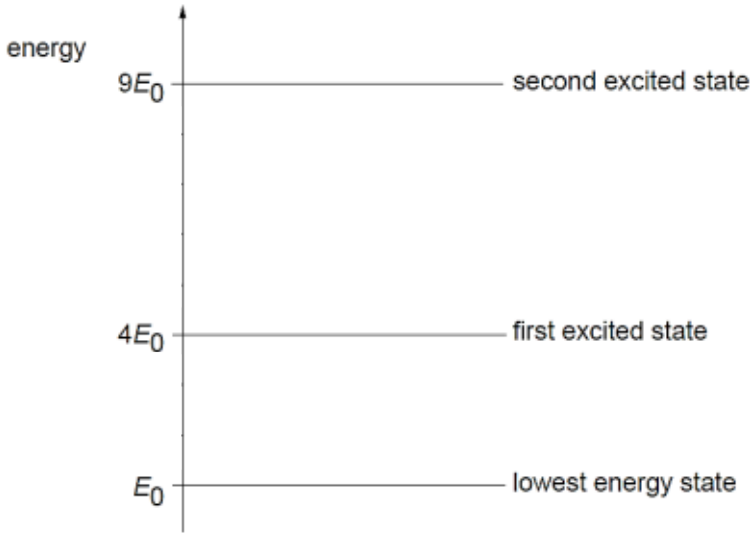


Fig. 5.1

(a) When photons of green light are absorbed by the dye molecules, the electron jumps from the lowest energy state to the second excited state. Green light has a wavelength of 510 nm.

Use Fig. 5.1 to show that E_0 is about 5×10^{-20} J.

[2]

(b) An electron in the long molecule described above is free to move along the length of the molecule but not beyond the length of the molecule.

This suggests a simple model of a particle trapped in an infinite potential well of the length of the molecule L, where the potential energy of electron is infinitely large beyond the molecule and zero when it is in the molecule. (Fig. 5.2).

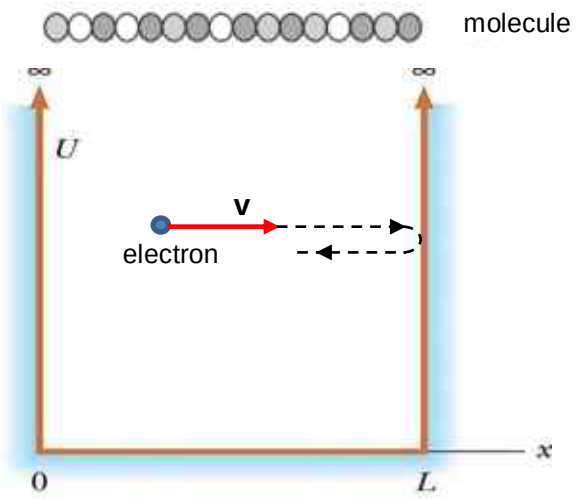


Fig. 5.2

Fig. 5.3 shows a wave-function for an electron when it is at the lowest energy state, E_o

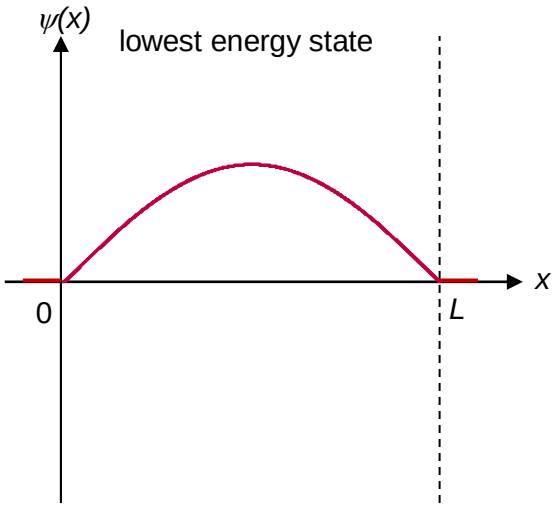


Fig. 5.3

(i) Explain why the wave function of the electron is zero for positions x of the electron at $x < 0$ and $x > L$.

.....

.....

.....

.....

..... [2]

(ii) Suppose the electron of mass m has a de Broglie wavelength of λ.

Show that the de Broglie wavelength of the electron is given by $\lambda = \frac{h}{\sqrt{2mE}}$ if it has a total energy of E.

[3]

(iii) Determine the length L of the molecule.

L = ... m [2]

(iv) With the aid of Fig. 5.1 and relationship in **(b)(ii)**, sketch in Fig. 5.4 a wave function for the electron when it is at the *second* excited state.

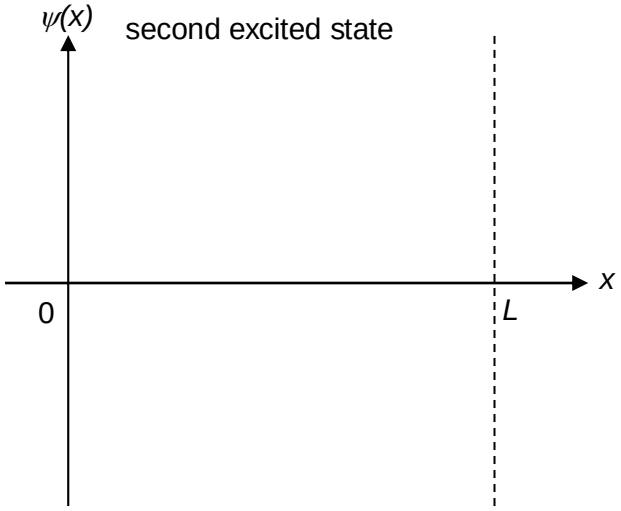


Fig. 5.4 [1]

6 In the USA, cars account for about half the oil consumed, half the urban pollution and a quarter of emission of greenhouse gases. Vehicle usage is set to continue its growth globally. With improved technology over the past decade, electric vehicle is touted to be a greener alternative to conventional cars powered by fossil fuels.

The following tables gives the specifications of variants of the same model of car, Ford Focus, one oil-powered (named 'Classic') and one electric-powered (named 'Electric'),

Specifications for Two Variants of Ford Focus:

Electric [1] :

Capacity of lithium-ion battery	23 kWh
Average distance per full charge	122 km
Carbon dioxide emission per MWh of electricity generated from fossil fuel [2].	601 kg

Table 6.1(a)

Classic[1]:

Distance per litre of petrol	29.1 km
Carbon dioxide emission per km travelled	105 g
Energy released in combustion of 1 litre of petrol	9.7 kWh

Table 6.1(b)

Sources:

1. US Energy Information Administration, Ford Motor, Wikipedia.

2. Tan, Wijaya and Khoo. (2010). Life cycle analysis of fuels and electricity generation in Singapore.

(a) One of the key advantages of electric vehicles over conventional oil-powered vehicles is energy efficiency, this can be measured by comparing the *average energy expenditure per kilometer* for each variant.

Using the data quoted in Table. 6.1(a) and 6.1(b),

(i) show that for the Electric variant, the energy stored in the lithium-ion battery when fully charged is 8.28×10^7 J. [1]

(ii) Hence, calculate the *average energy expenditure per kilometer travelled* for the Electric variant.

Electric variant: ..... kJ km^{-1} [2]

(iii) Calculate the *average energy expenditure per kilometer travelled* for the Classic variant.

Classic variant: ..... kJ km^{-1} [2]

(b) However, in many countries, electricity is generated through the burning of fossil fuel. Electricity generated through such a method has a *yield of about 30%*.

(i) Explain what you understand by '*yield of about 30%*'?

.....

..... [1]

(ii) Assuming that the electricity used for charging the lithium-ion battery in the Electric variant is generated through burning of fossil fuel, using **(a)(ii)**, determine the actual energy expenditure per kilometer for the Electric variant.

energy expenditure = ... kJ km^{-1} [1]

(c) There have been calls by members of public for the Singapore government to provide more tax rebates for consumers purchasing electric cars as part of government's effort to encourage environment conservation efforts.

One way to measure how environmentally friendly a car is look at its carbon footprint (carbon dioxide emitted per kilometer).

(i) Assuming that the electricity in Singapore's power plants is generated from fossil fuels, using Table 6.1(a), calculate the amount of carbon dioxide emitted per kilometer for the Electric variant.

Amount emitted per kilometer = ... g [2]

(ii) Comment on whether the Electric variant of Ford Focus is more environmentally friendly than the Classic variant, in the context of Singapore.

.....

.....

..... [2]

(d) One of the key challenges facing electric car manufacturers is how to reduce the long charging time for the vehicular battery pack.

A particular electric car has a charging power rating of 20 kW. However, the charging power will decay as the battery gets charged up. It takes about 5 hours for the battery pack to charge fully from empty state. Figure 6.2 shows how the charging power vary with time.

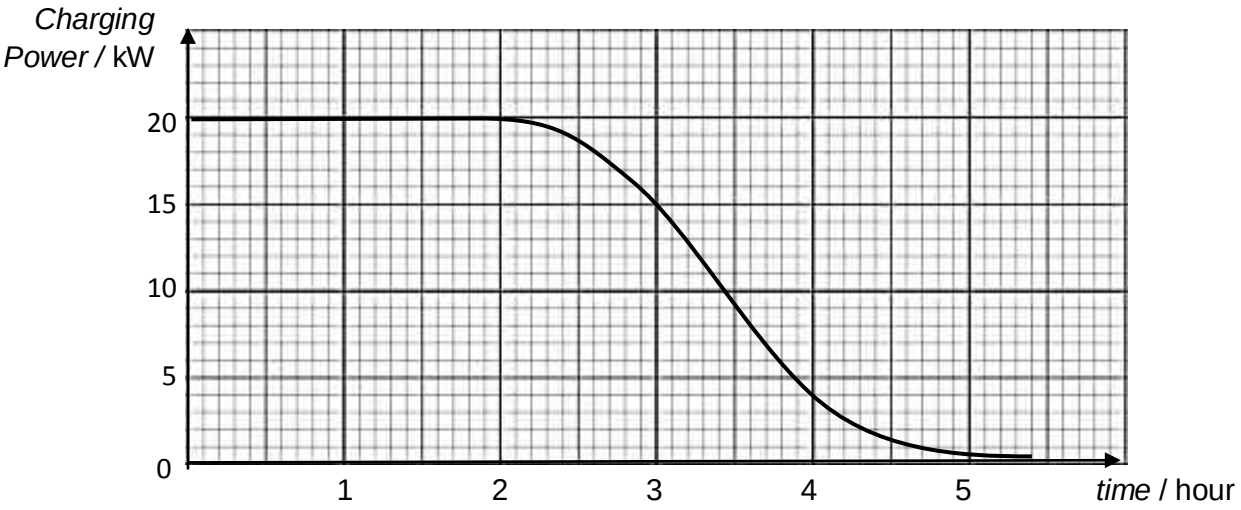


Fig. 6.2

(i) Estimate the amount of energy that the battery can store at full capacity.

capacity = ... kWh [3]

(ii) Another manufacturer has invented a better charging technology that allows the decay in charging power to be delayed.

Assuming that the maximum charging power of this charger is still 20 kW and that the capacity of the battery remains the same, sketch on Fig. 6.2 its corresponding charging curve for the same battery and label it **A**. [1]

7 A student is investigating simple harmonic motion using an electric oscillator. A plate is attached to the top of the electric oscillator. A small mass is placed on the metal plate as shown in Fig. 7.1.

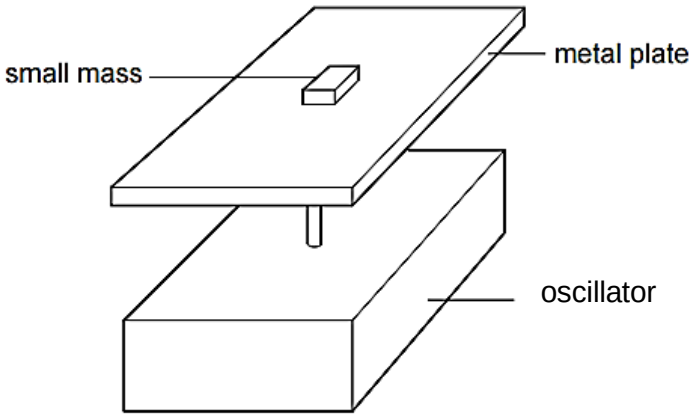


Fig. 7.1

An alternating potential difference (p.d.) is applied to the oscillator. For a given peak p.d. V, there is a maximum frequency f at which the small mass remains in contact with the plate. The contact between the small mass and the plate is lost when the frequency is greater than f.

Design a laboratory experiment to investigate the relationship between f and V.

You may assume that a signal generator is available. However, the scale of this generator is unreliable and cannot be use to give an indication of frequency. No other signal generator is available. Any other standard equipment, which may be found in a school or college science laboratory, can be used.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) how the frequency would be measured,

(c) the control of variables,

(d) how the relationship between f and V is determined,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Diagram:

End of Paper

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**15S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9646/03

Paper 3 Longer Structured Questions

16 September 2016

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly 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, paperclips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions. Circle the questions attempted.

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		
1		9
2		11
3		11
4		9
5		20
6		20
7		20
Deductions		
Total		80

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, $\phi = -\frac{Gm}{r}$

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, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** questions in the spaces provided.

1 (a) A crane consists of a freely pivoting beam of mass 200 kg. The centre-of-mass of the beam is 4.0 m from the pivoting joint. The cable at one end of the beam, 12.0 m from the joint, is used to lower a concrete block of mass 5.0 x 10^3 kg into the sea. There is a counterweight of mass 3.0 x 10^4 kg at the other end of the beam and its centre is 1.0 m from the joint. The top of the crane is 3.0 m above the joint and there is a support line connecting it to the part of the beam where the cable is attached.

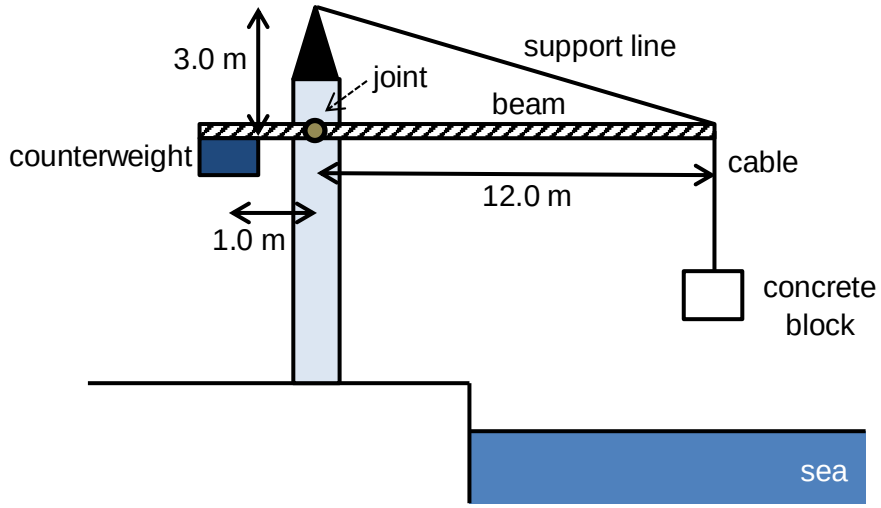


Fig. 1.1

(i) Define the *moment of a force*.

……

……

…… [1]

(ii) Calculate the tension in the support line as the block is lowered towards the sea at a constant speed.

tension = …… N [3]

(b) After a few minutes, the concrete block is totally immersed in the sea water.

(i) On Fig. 1.2, label all the forces acting on the concrete block as it is lowered to a greater depth at a constant speed.

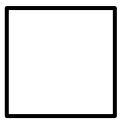


Fig. 1.2

[3]

(ii) Explain how the tension in the cable changes as the concrete block is lowered from a depth of 10.0 m to a depth of 20.0 m at the same constant speed.

……

……

……

……

…… [2]

2 A wine glass can be shattered by exposing it to a high intensity sound wave.

Fig. 2.1 shows the shape of the rim of a wine glass when viewed from above at an instant in time when the glass is exposed to a high intensity sound of frequency F. The dotted circle of radius r is the original shape of the glass when it is not vibrating.

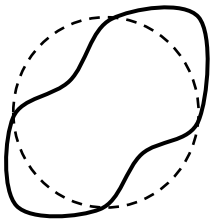


Fig. 2.1

(a) Determine an expression for the speed of the wave in glass v in terms of r and F.

v = ... [2]

(b) The wave in the glass is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(a)**.

.....

.....

.....

.....

..... [3]

(c) The wine glass has a set of natural frequencies of vibrations associated with it. On Fig. 2.2, sketch the fundamental mode of vibration that can be set up in the wine glass.

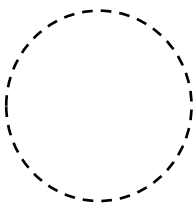


Fig. 2.2

[1]

(d) Write down an expression for all the possible frequencies of vibration f that can be set up in the glass in terms of v and r.

f = ... [2]

(e) Explain why, in Fig. 2.1, the wine glass in vibration only shows it in that particular mode of vibration and not any of the other possible modes of vibration.

.....

.....

.....

..... [2]

(f) Explain why there is a delay from the time the wine glass is exposed to the high intensity sound before it shatters.

.....

.....

.....

..... [1]

3 **(a)** State the *laws of electromagnetic induction*.

……

……

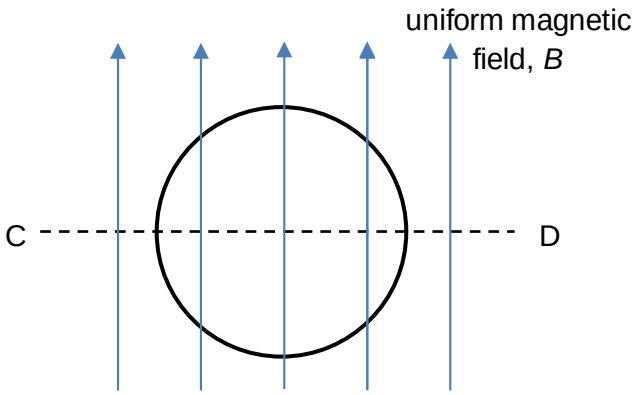
……

……

……

…… [4]

(b) Fig. 3.1 shows a circular coil of wire immersed completely in a uniform magnetic field of flux density 5.0 x 10^{-5} T. The coil has 400 turns, a resistance of 4.0 Ω and an area of 25 cm^2.



Plan view

Fig. 3.1

The coil is rotated about the axis CD at constant angular velocity.

(i) Sketch, on Fig. 3.2,

1. the variation of the magnetic flux linkage with time for one complete cycle. [1]
2. the variation of the induced e.m.f. with time for one complete cycle. [2]

Label the two graphs clearly.

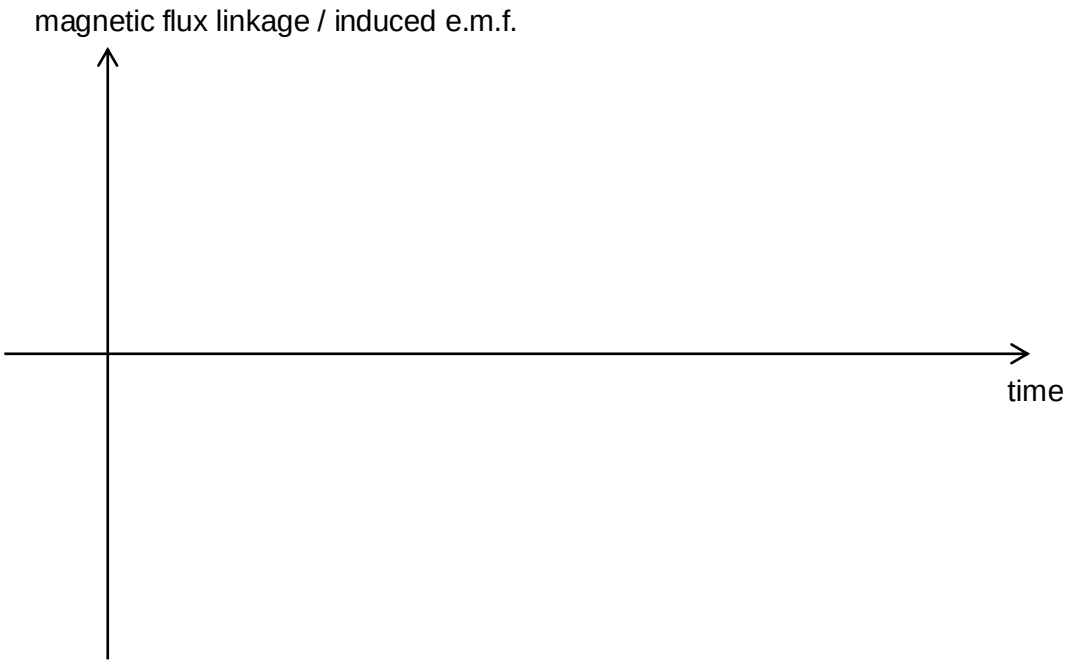


Fig. 3.2

(ii) Calculate the amplitude of the induced e.m.f. when the coil is rotating at a constant angular velocity of 8.0 rad s^{-1}.

e.m.f. = …… V [2]

(iii) Draw, on Fig. 3.1, the direction of the induced current when the coil rotates in a clockwise direction when it is viewed from C. [1]

(iv) The coil is changed from one with a circular cross-sectional area to one with square cross-sectional area but both has the same cross-sectional area. Comment, with an explanation, the change of your sketch of the induced e.m.f. in **(b)(i)** if any.

……

……

…… [1]

4 (a) Uranium-238 decays into lead-206 by several stages. Lead-206 is a stable isotope. The overall decay can be represented by the following equation:

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + \text{decay products}$$

It is suggested that **all** of the decay products are alpha particles.

Use the equation to show that this cannot be correct.

[2]

(b) Technetium-99, $^{99}_{43}Tc$ decays to ruthenium-99, $^{99}_{44}Ru$ via the emission of one radioactive particle. The half-life of technetium is 4.00×10^6 years. Ruthenium-99 is a stable nuclide.

(i) Write down the nuclear equation representing this decay.

[1]

(ii) Define *half-life*.

……

……

…… [1]

(iii) Determine the decay constant of technetium-99.

decay constant = ... year $^{-1}$ [1]

(iv) On the axes of Fig. 4.1, sketch a graph to show how the ratio

$$R = \frac{\text{number of ruthenium-99 nuclei}}{\text{number of technetium-99 nuclei}}$$

will change in a sample with time t.

Take $t = 0$ to be the instant of creation of technetium-99.

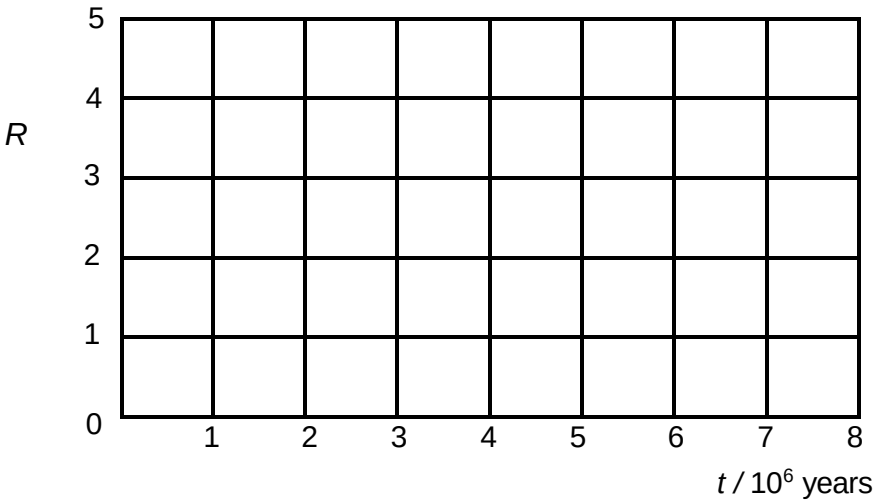


Fig. 4.1 [2]

(v) Determine the time it takes for the R value of the sample to be $R = 0.81$.

time = ... years [2]

Section B

Answer **two** questions from this Section in the spaces provided.

5 (a) Fig. 5.1(a) shows a novel method of making a *lightcraft* which is powered by a pulsed infrared laser beam that is mounted on Earth.

Air from the front of the craft is directed to the 'engine' which is essentially a cylindrical vessel fitted with an exhaust nozzle (Fig 5.1(b)). The energy in the laser beam is reflected onto the air in the 'engine' in the cylindrical vessel which is rapidly heated to a temperature of about 40,000 K. This causes the air to expand explosively in the 'engine', ejecting the air at high speed backwards.

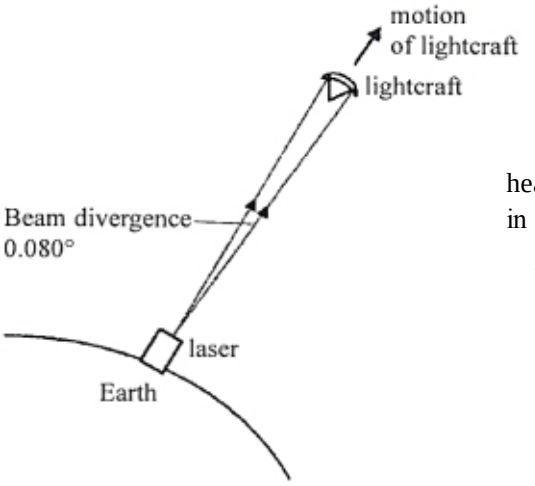


Fig. 5.1(a)

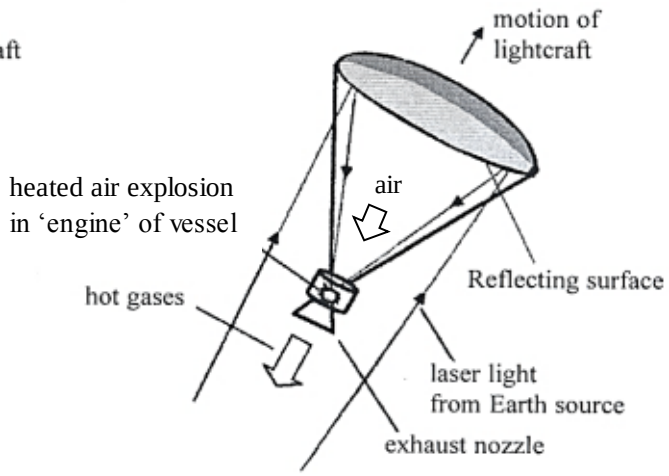


Fig. 5.1(b)

In a particular experiment, a 2.00 kg *lightcraft* will be propelled vertically using laser. This *lightcraft* will reach a speed of five times the speed of sound at the end of its first 30 km of flight. The speed of sound may be assumed to be 340 m s^{-1}.

(i) Explain, using Newton's laws of motion, how the *lightcraft* is being accelerated.

……

……

……

……

……

…… [3]

(ii) Calculate the *average* resultant force experienced by the *lightcraft* during the first 30 km of the flight.

resultant force = …… N [3]

(iii) The air in the 'engine' of the *lightcraft* is initially at a temperature of 300 K and a pressure of 1.0×10^5 Pa. Assuming that the air behaves like an ideal gas, calculate the pressure of the air after being heated by the laser.

pressure = …… MPa [2]

(iv) After the first 30 km of flight, the *lightcraft* will switch to a hydrogen propulsion system instead. Explain why it is necessary to do so.

……

……

……

…… [2]

(b) It can be proven theoretically that a heat engine working between two temperatures is most efficient when its cycle of operation consists of two adiabatic changes and two isothermal changes. This is illustrated by the pressure-volume graph in Fig. 5.2 for an engine which uses an ideal gas.

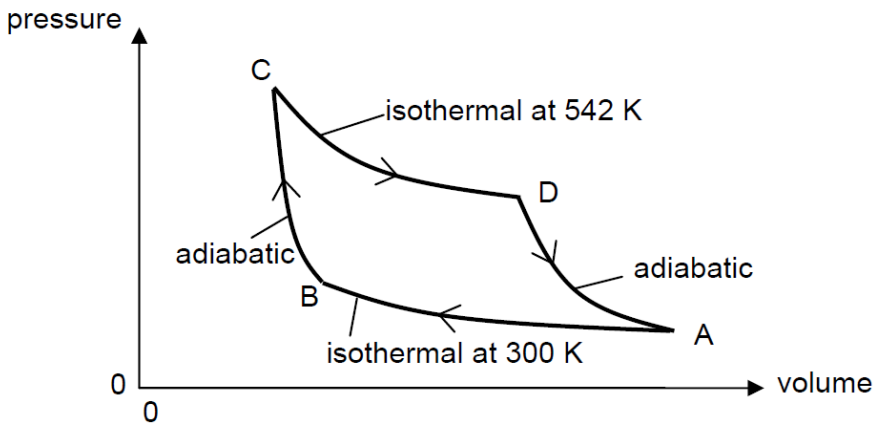


Fig. 5.2

(i) Explain what is meant by *internal energy of a gas*.

……

……

……

…… [2]

(ii) The table below provides some values for the changes in each of the stages for a monatomic gas. Complete the table.

	heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B	- 41.1		
B to C	0		47.2
C to D	70.8		
D to A	0		

[4]

(iii) Calculate the efficiency of this engine, which is given by the *ratio of the net work done by the gas to the heat supplied to the gas*.

efficiency = ... % [2]

(iv) Internal energy of a monatomic gas is given by 3/2 *NkT*, where *N* represents the number of molecules, *k* the Boltzmann constant and *T* the thermodynamic temperature. Deduce the number of molecules present in the ideal gas.

number of molecules = ... [2]

6 **(a)** Give an explanation why the difference in potential across certain electrical components is labelled as *electromotive force* while across some others is labelled simply as *potential difference*.

……

……

……

……

…… [2]

(b) Fig. 6.1 is a bridge circuit. It consists of a one-meter resistance wire AB connected to a cell of e.m.f. *E*. The other two resistors, X and Y have resistance 30 Ω and R_y respectively. The potential difference between two points i and j is denoted as V_{ij}.

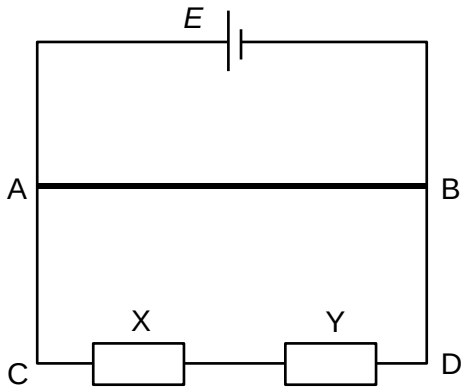


Fig. 6.1

(i) What is the relationship between V_{AB} and V_{CD} ?

[1]

(ii) When a sensitive galvanometer is connected across PQ as shown in Fig. 6.2, it gives a zero reading.

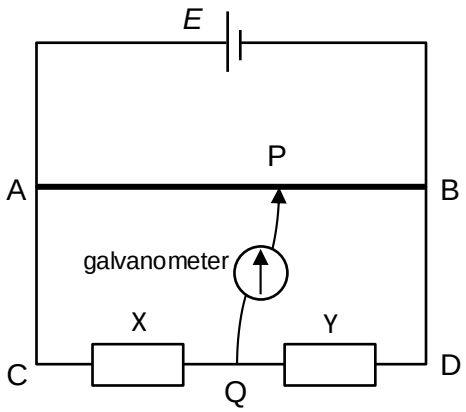


Fig. 6.2

Explain why the current through AP and PB is the same.

……

……

……

…… [2]

(iii) Write down the relationship linking V_{AP}, V_{PB}, V_{CQ} and V_{QD}.

[1]

(iv) Given the length AP = 60 cm, calculate the value of R_y.

R_y = ... Ω [3]

(v) Explain how the length AP will change, if any, if the internal resistance of the cell is not negligible.

……

……

…… [1]

(vi) Point P is shifted from its original location to the midpoint of AB. State the direction of the conventional current through the galvanometer.

direction : ……..... [1]

(vii) Suggest a practical usage of this circuit.

……

……

……..... [1]

(c) A voltage supply V_s has the waveform as shown in Fig. 6.3.
The curve portion of the voltage is sinusoidal.

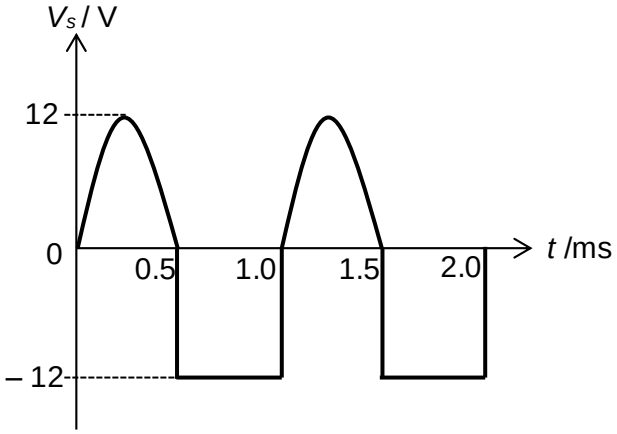


Fig. 6.3

(i) Calculate the root-mean-square voltage of this supply.

root-mean-square voltage = ...V [3]

(ii) The voltage supply is connected to a circuit as shown in Fig. 6.4. Each of the three resistors has a resistance of 10 Ω. The two diodes can be taken to be ideal. When terminal X is at higher potential, the value of the voltage as seen in Fig. 6.3 is taken to be positive.

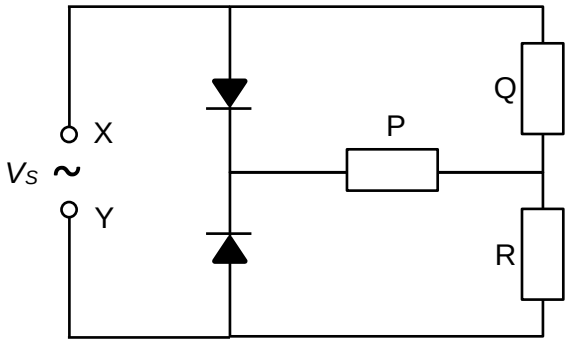


Fig. 6.4

Draw a simplified circuit diagram when terminal X of the supply is at higher potential.

[1]

(iii) Calculate the maximum potential difference across resistor P when terminal X of the supply is at higher potential.

potential difference = ... V [2]

(iv) Hence sketch on Fig. 6.5 how the potential difference across resistor P varies with time when terminal X of the supply is at higher potential.



[2]

Fig. 6.5

7 In 1932, Ernest Lawrence built the first cyclotron, an early form of particle accelerator that accelerates charged particles in a confined space with a combination of electric field and magnetic field. Though it was succeeded by more powerful designs later, the cyclotron is still used in nuclear medicine today.

Fig. 7.1 shows the basic structure of a cyclotron. A pair of electromagnets generate a uniform magnetic field vertically through a pair of semicircular metal chambers, referred to as “dees”. The dees are hollow, allowing charged particles to move. An AC supply is connected to the dees.

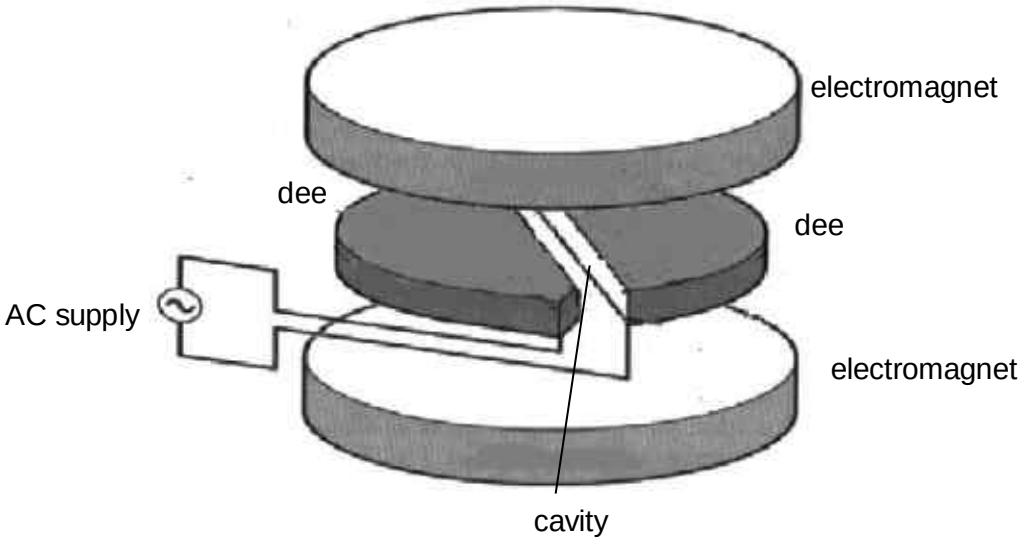


Fig. 7.1

Fig. 7.2 shows the top view of the dees. A potential difference is applied across the dees to generate a uniform electric field as protons are injected at negligible initial speed. There is no electric field elsewhere. The protons are accelerated to D1, in which it moves in a semi-circular path as indicated by the dotted line. Note that the diagram is not drawn to scale. The actual gap between the two dees is very small, so that the time taken for the proton to cross from one dee to another is negligible. The magnetic field also has negligible effect on the protons while they are moving between the dees.

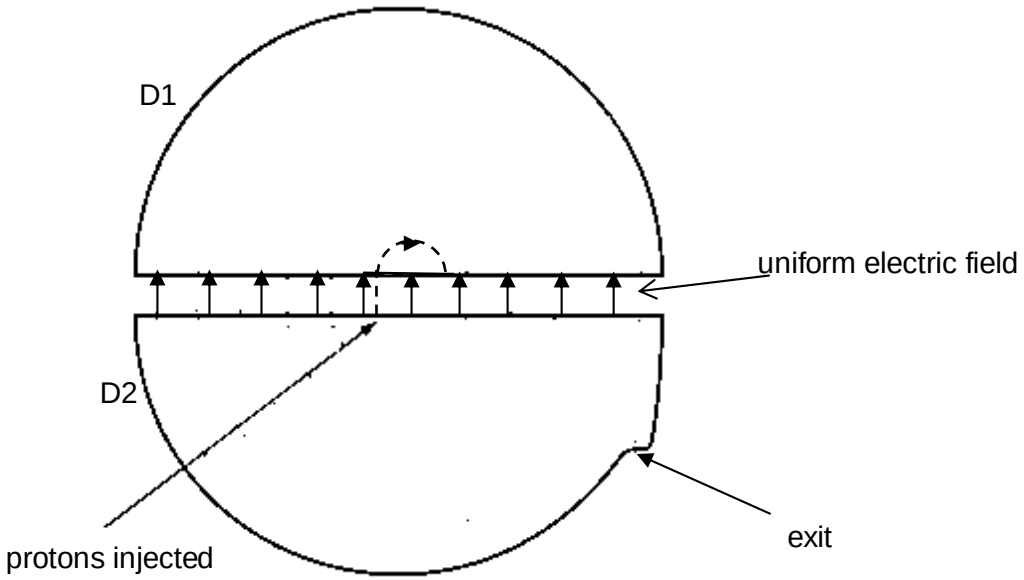


Fig. 7.2

(a) Refer to Fig. 7.2.

(i) State the direction of the magnetic field. Explain why the proton moves in the semicircular path indicated.

……

……

……

……

…… [3]

(ii) Show that the radius of the semi-circular path of the proton, r, is

$$r = \frac{mv}{Be}$$

where m is the mass of proton
v is the speed of proton
B is the magnetic flux density
e is the elementary charge

[2]

(iii) Hence, show that the time t to travel in D1 until it emerges from the gap is

$$t = \frac{\pi m}{Be}$$

[1]

(b) The AC supply is set such that when the proton emerges from D1, the polarity of the applied potential difference changes while the magnitude remains the same. As a result, the emerging proton is accelerated towards D2. This process is repeated until the proton exits the cyclotron. A plausible path of a proton within the dees is depicted in Fig. 7.3.

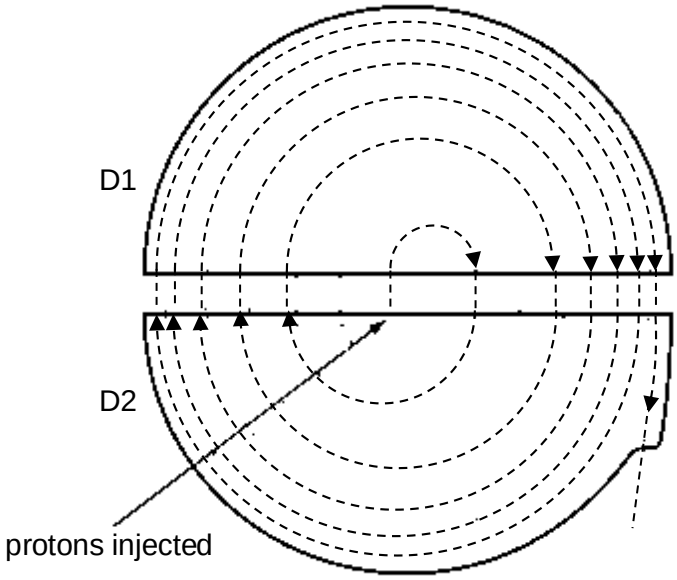


Fig. 7.3

(i) Explain why

1. the radii of the proton's semi-circular path progressively increase.

……

……

…… [2]

2. the magnitude of increase in radii of subsequent semi-circles decreases.

……

……

…… [2]

3. the alternating current has a constant frequency despite the changing speed of the proton.

……

……

…… [2]

(ii) Sketch on Fig. 7.4, the variation of the speed of a proton with time as it goes through **four** semi-circles, starting from the moment it is injected.



Fig. 7.4

[3]

(iii) Show that the output energy E of a proton is given by

$$E = \frac{e^2B^2R^2}{2m}$$

where R is radius of the dees.

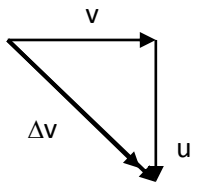
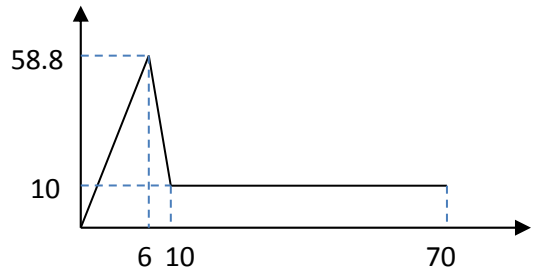
[3]

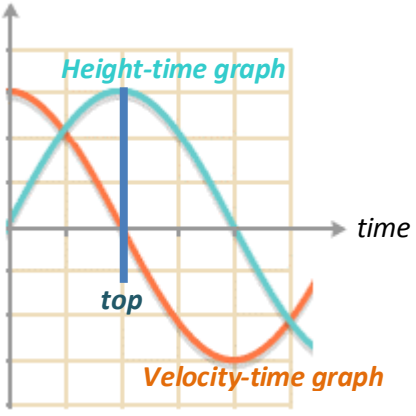
(iv) A typical large cyclotron in the 1950s used a magnetic field of flux density of about 2.0 T and the dees had a radius of 2.3 m. Calculate the maximum theoretical energy of protons collected at the exit in MeV.

energy = ... MeV [2]

End of Paper

2016 HCI JC2 Preliminary Examinations H2 Physics Prelim Paper 1 Solutions and Explanations

QN	Ans	Explanation
1	D	Energy = power/time, or Energy = work done = force x displacement Units of energy = W s = N m = kW h
2	A	$\Delta v = v - u$ 
3	C	$s = ut + \frac{1}{2}at^2 = \frac{1}{2}at^2$ (since balls are dropped from rest) Based on s-t graph, at equal intervals of s, time intervals becomes smaller.
4	C	$s = ut + \frac{1}{2}at^2$ $-2.5 = 30\sin 5^o\, t + 2(-9.81)t^2$ $t = 1.0\ s$
5	B	Sketch the v-t graph and find area under graph. Height = 0.5(6)(58.58) + 0.5(4)(48.8) + 10(70-6) = 914 
6	C	There is a constant force, hence a constant deceleration. The momentum will decrease at a constant rate. However, the displacement will increase at a decreasing rate. OR Since $p = mv$, the graph of p against s is the same trend as the graph of v against s. Given constant deceleration, $v = \sqrt{u^2 - 2as}$
7	C	Applying conservation of linear momentum, we find that the speed after the collision is 2.0 m s^{-1}. Hence, the total kinetic energy after the collision is ½ m_{tot} v^2 = 0.5 x 15 x 2.0^2 = 30 J. Furthermore, the force on either trolley is $\Delta p/\Delta t$ = 20/0.20 = 100 N.
8	C	Relative speed of approach = relative speed of separation $v_1 - v_2 = u_2 - u_1$ $v_\alpha - v_p = u_p - u_\alpha$ $-v - 4v = u_p - u_\alpha$ $-5v = u_p - u_\alpha$ --- (1)

		By the principle of conservation of linear momentum, $m\ u_p + 4m\ u_\alpha = 0$ $u_p = -4u_\alpha$ --- (2) Combining (1) and (2), $-5v = -4u_\alpha - u_\alpha$ $v = u_\alpha$ $u_p = -4u_\alpha = -4v$
9	**D**	By the principle of floatation, the weight of A and the weight of B are equal to the weight of a pail that would simply be filled by water to the brim. However, for pail C, it is mentioned that the block is resting on the pail's bottom. Thus, the block's weight is equal to the upthrust plus the normal contact force. In other words, the block's weight in pail C is larger than that of the fluid displaced, so the total weight of pail plus water + block will be larger than if there were only water.
10	**A**	• In the first 5 seconds, the height increases at a constant speed. This means that GPE increases at a constant rate and KE did not increase. So power is constant. • In the next 4 seconds, the height is constant, so this means there is no change in GPE and KE too. So power supplied is zero.
11	**D**	$Fc = m\omega^2 r$. Both objects have the same angular velocity, but the centripetal force required for Q is larger due to larger radius. When the centripetal force required exceeds the friction available, Q starts to slide.
12	**C**	Horizontally: $P\sin\theta = mr\omega^2$ where tension: P Vertically: $P\cos\theta = mg$ Hence, $\tan\theta = \frac{r\omega^2}{g} = \frac{4\pi^2 r^2}{gT^2} \Rightarrow T = \sqrt{\frac{4\pi^2 r^2}{g\tan\theta}}$
13	**B**	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ $GM = rv^2$ $r_x v_x^2 = r_y v_y^2$ $\frac{v_x}{v_y} = \left(\frac{r_y}{r_x}\right)^{1/2} = \left(\frac{1}{4}\right)^{1/2} = \frac{1}{2}$
14	**A**	Work done by a conservative force results in a change in its associated potential energy.
15	**A**	Base on her description of motion of the capsule, a displacement-time graph is plotted. From the velocity-time graph, she will see the capsule coming up at maximum speed. Continuously decelerating (though not uniform) Finally come to a stop at the top. 
16	**A**	The frequency of oscillation is determined by the driver.

17	**B**	At compression region of a wave traveling towards the right, the adjacent molecule on its left must have positive displacement.
18	**C**	Node-to-node distance is half the wavelength of the incident wave. The side of the water tank is an anti-node.
19	**A**	First evaluate the wavelength in terms of *L* for the first straw then use this wavelength to find the length of the second straw.
20	**B**	A fundamental temperature scale is one which does not depend on the properties of the materials used.
21	**D**	As the ideal gas is pulled quickly, no heat is loss. Negative work is done in pulling it gas. By first law of thermodynamics, internal energy decreases and therefore temperature decreases. The decrease in temperature also suggests that the RMS speed has decreased. Density decreases as volume increases. As temperature decreases and volume increases, using *pV=nRT, p* would decrease.
22	**C**	*pV = nRT* *1/p = (1/(nRT))V* Gradient is given by *1/(nRT).* When *n* is changed to *4n*, *T* to *½ T*, gradient is halved.
23	**C**	Gain in KE = Loss in EPE $\frac{1}{2}mv^2 = q\Delta V$ $\Rightarrow \frac{p^2}{2m} = q\Delta V$ $\Rightarrow p \propto \sqrt{mq\Delta V}$ $\therefore \frac{p_\alpha}{p_{proton}} = \sqrt{\frac{4}{1}\times\frac{2}{1}\times\frac{2}{1}} = 4$
24	**D**	Points X and Y have the same potentials. Thus, no change in EPE. By conservation of energy, no change in EPE means no W.D. by external force.
25	**C**	Increase in potential difference leads to increase in electric field hence acceleration. Current increases when charge carriers move faster through the resistor.
26	**C**	$V_{XS} = V_{XY}\left(\frac{L_1}{L_1+L_2}\right)$ by potential divider principle $\therefore\ V_{XY} = V_{XS}\left(\frac{L_1+L_2}{L_1}\right) = 1.02\left(\frac{L_1+L_2}{L_1}\right)$
27	**A**	Circuit (i) $P = I^2R = \left(\frac{4.5}{R+3r}\right)^2 R$ Circuit (ii) $P = I^2R = \left(\frac{1.5}{R+3r}\right)^2 R$

		Therefore $\frac{\text{power in R in circuit (i)}}{\text{power in R in circuit (ii)}} = \left(\frac{4.5}{R+3r}\right)^2 R \div \left(\frac{1.5}{R+3r}\right)^2 R = \left(\frac{4.5}{1.5}\right)^2 = 9$
28	**A**	$P = I^2 R = \left(\frac{5}{\sqrt{2}}\right)^2 \times 10 = 125\,W$
29	**C**	$\frac{V_S}{V_P} = \frac{5}{1} \Rightarrow V_S = 5 \times 240 = 1200\,V$ Power delivered to the resistive load $P = \frac{V^2}{R} = \frac{1200^2}{1000} = 1440\,W$ Ideal transformer implies 100% efficiency. Power supplied by primary circuit $P = V\,I = 240\,I = 1440 \Rightarrow I = \frac{1440}{240} = 6\,A$
30	**B**	RS has a perpendicular section equal to RQ. No force on either PQ or ST.
31	**A**	The effective magnetic field (component perpendicular to the wire) at P and R are opposite in direction, hence producing magnetic forces opposite in direction.
32	**A**	When view from the top (i.e. plan view), the length of the rod is not cutting the magnetic field. Thus, no induced e.m.f. OR Consider a free electron in the rod. As the rod moves down, applying Fleming's left hand rule, the direction of the magnetic force will be into the page. Since there is no movement of charges towards either end P or Q, there is no pd set up across PQ.
33	**A**	The induced current in the inner loop should be decreasing in the clockwise direction. Based on Lenz's law, the direction of induced current should be in same direction to oppose the change in B-field from outer loop. The induced current is proportional to the gradient of current vs time graph.
34	**C**	The threshold frequency is smaller for metal X than for metal Y. But $\lambda = \frac{c}{f}$, hence, a smaller frequency implies a larger wavelength.
35	**D**	The characteristic line corresponding to transition between K and L is K_α which is about 7.4 x 10^{-11} m. The given energy corresponds to the K_β line.
36	**B**	Options A, C and D are correct statements but are not the conclusions from alpha-scattering experiment.
37	**C**	A/2 = 235/2 ~ 118 For A = 235, BE/A ~7.6 MeV; for A = 118, BE/A ~ 8.5 MeV Energy released = (8.5)(235) – (7.6)(235) = 212 MeV ~ 200 MeV
38	**A**	$R = \lambda N \Rightarrow N = \frac{R}{\lambda} = \frac{R\tau}{\ln 2}$ 1 mole – *L no. of radioactive* nuclei – *A* g N nuclei - $N \times \frac{A}{L} = \frac{R\tau}{\ln 2}\frac{A}{L}$ g (Ans)

		All options have been made dimensionally consistent to yield a mass quantity and hence students cannot use that to deduce the correct option.
39	**C**	Excitation of atoms in the lasing medium can only be done by either stimulated absorption or particles collisions.
40	**C**	When a current flows through it, mobile electrons flows in opposite direction to that of mobile holes. Thus, the total current flow is the sum of both 'hole' and 'electron' currents.

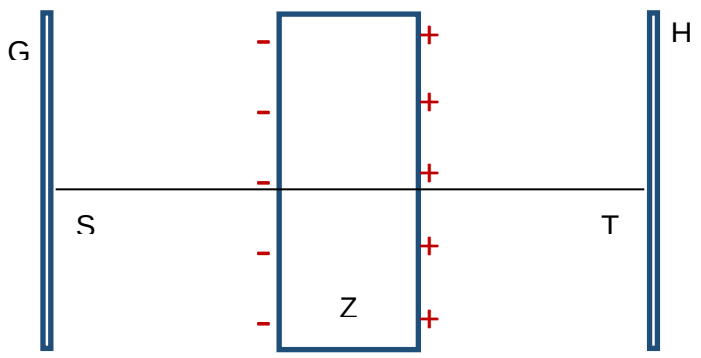
HCI 2016 C2 H2 Physics Preliminary Examination Paper 2 Suggested Solution

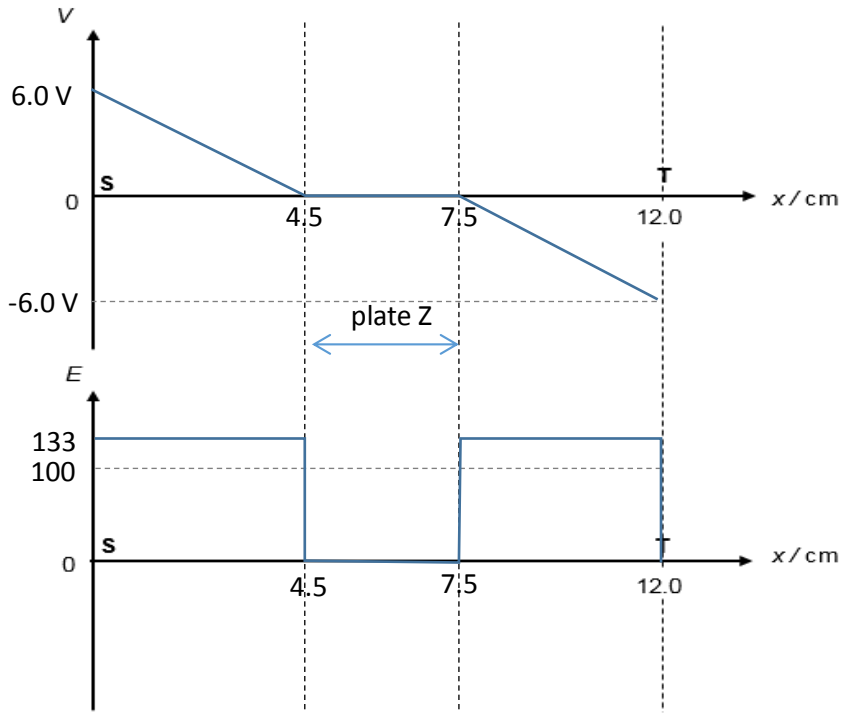
Question	Answer	Marks
1(a)(i)	Method 1: Using equations of motion Taking downwards to be positive: $v^2 = u^2 + 2as = 1.5^2 + 2(9.81)(0.65)$ $v = \pm 3.9 \text{ m s}^{-1}$ Final speed = 3.9 m s^{-1} OR Method 2: Using conservation of energy Loss in GPE = Gain in KE $mgh = \frac{1}{2}m(v^2 - u^2)$ $v^2 = 2gh + u^2$ $v = 3.9 \text{ m s}^{-1}$ Final speed = 3.9 m s^{-1}	M1 A1
1(a)(ii)	 • Straight line from X to t_1 • Straight line from X to – 3.9 m s^{-1} • Gradient straight line from t_1 to t_2 must be parallel to line is segment • Steep line may join the two straight lines but its width must be narrow.	A3
1(a)(iii)	The speed of the ball after **rebound is less than the speed just before impact**. The ground/Earth is assumed to be stationary, hence there is a **loss in the kinetic energy of the system** during the bounce. The bounce is **inelastic.**	B1 B1
1(b)	See blue graph above • correct curvature with smaller impact and rebound speed	A1
	Max Marks	**8**

Question	Answer	Marks
2(a)	Change in gravitational potential energy: $\Delta GPE = GPE_S - GPE_H$ $= -\frac{GMm}{r_s} - (-\frac{GMm}{r_H})$ $= -(6.67\times10^{-11})(7.0\times10^{24})(1.8\times10^{18})(\frac{1}{6.0\times10^{6}} - \frac{1}{5.0\times10^{7}})$ $= -1.23\times10^{26}$ J	**M1** **A1**
2(b)(i)	The area between the graph and the r-axis from r = 6 x 10^6 m to r = 50 x 10^6 m.	**A1**
2(b)(ii)	The lost in GPE of the system is released as the kinetic energy of the mass. Hence its speed increases. The lost in GPE increases (or the magnitude of g increases) as it approaches the planet OR The force acting on the asteroid increases as it gets closer to the surface of the planet Hence its acceleration increases.	**M1** **A1** **M1** **A1**
2(b)(iii)	If the separation is large, the planet and asteroid can be approximated to be point masses. If the graph follows Newton's law of gravitation, the shape should be the same. As the asteroid approaches the planet, the rotation of the planet plays a part in changing the shape of the graph when - the shape of the planet deforms due to the rotation, - the density of the planet is not constant for any particular radius.	**A1** **M1**
	Max Marks	**7**

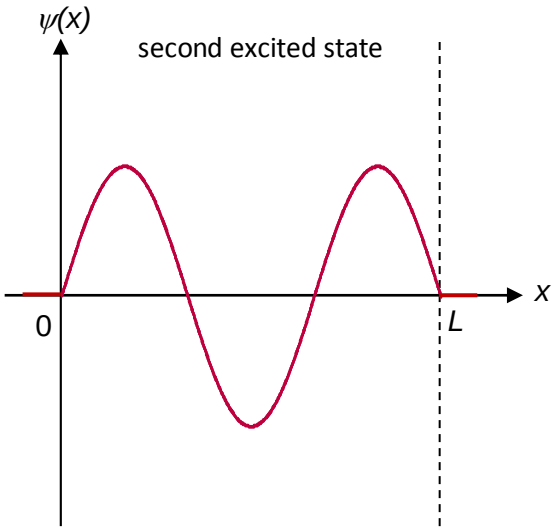
Question	Answer	Marks
3(a)	Hooke's Law states that the magnitude of force F exerted by a spring on a body attached to the spring is proportional to the extension x of the spring from relax position provided the proportional limit of the spring is not exceeded.	**B1**
3(b)(i)	Extension of the spring is $2e$. $F = 2ke$	**B1**
3(b)(ii)	$U = \frac{1}{2}k(2e)^2 = 2ke^2$	**M1**
3(b)(iii)	Loss in elastic potential energy = gain in kinetic energy of the two spheres $2ke^2 = \frac{1}{2}mv_o^2 + \frac{1}{2}mv_o^2$ $v_o = \sqrt{\frac{2ke^2}{m}} = \sqrt{\frac{2(15)(2.5\times10^{-2})^2}{(0.050)}}$ = 0.612 m/s [-1] if the first statement is not given	**M1** **A1**

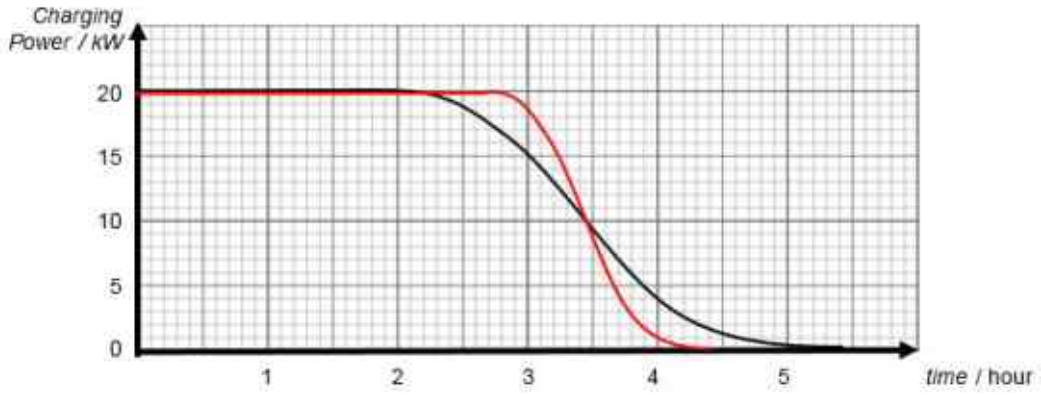
3(b)(iv)	$2ke^2 = \frac{1}{2}mv_o^2 + \frac{1}{2}mv_o^2$ $2ke^2 = mv_o^2$ $v_o = \left(\sqrt{\frac{2k}{m}}\right)e$ This resembles the equation $v_o = \omega x_o$ Amplitude of oscillation of each sphere $x_o = e =$ 2.5 x 10^{-2} m. Angular frequency $\omega = \frac{v_o}{x_o} = \frac{0.612}{2.5\times10^{-2}}$ = 24.5 rad s^{-1}	**M1** **A1** **A1 (units)**
3(b)(v)	According to the model, the restoring force is proportional to the extension from the equilibrium / force is linearly related to the separation. In reality the electric force between the atoms is a curve. OR According to model, the greater the separation, the greater is the restoring force. In reality, the restoring force between the atoms will only be greater for a limited range then after, for large distances, the restoring force will weaken. OR The vibration is only along a single axis. The vibration of a real molecules is three dimensional.	**B1**
	Max Marks	**9**

Question	Answer	Marks
4(a)	$E = -\frac{dV}{dx}$	**B1**
4(b)	$\lvert E\rvert = \left\lvert\frac{\Delta V}{\Delta x}\right\rvert = \frac{12.0\text{ V}}{12.0\times10^{-2}\text{ m}}$ $= 100\text{ N C}^{-1}$	**M1** **A1**
4(c)(i)	 • Sufficient charges and correct distribution. Spacing between charges must be even. • correct polarities on each side of the plate.	**B1** **B1**

4(c)(ii)	 Graph of V : [B1] Zero within AB; [B1] Correct shape outside AB with correct labels. Graph of E : [B1] Zero within AB (no ecf allowed); [B1] Correct shape outside AB with labels. Value of E must be coherent with E = -dV/dx	**B4**
4(c)(iv)	The net attractive electric force between the plate Z and the two plates (G and H) and hence an external force needs to do positive work to move plate Z to infinity. By conservation of energy, gravitational potential energy of the system should increase.	**M1** **A1**
	Max Marks	**11**

Question	Answer	Marks
5(a)	$9E_o - E_o = h\frac{c}{\lambda}$ $\Rightarrow E_o = \frac{hc}{8\lambda}$ $= \frac{(6.63\times10^{-34})(3.0\times10^{8})}{8(510\times10^{-9})}$ $= 4.875\times10^{-20} \sim 5\times10^{-20}$ J (Shown)	**M1 (conversion)** **M1** **A0**
5(b)(i)	$\lvert\psi(x)\rvert^2$ dx at a position x represents the probability of finding the electron in the small *dx*. Since, the electron cannot exist beyond the edges of the molecule, *the probability of finding it there is zero* and hence $\psi(x)$ must be zero.	**B1** **B1**
5(b)(ii)	Since potential energy of the electron within the molecule is zero, the energy of the electron is the kinetic energy of the electron:	**M1**

	$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ From de Broglie relationship : $p = \frac{h}{\lambda}$ Hence, $E = \frac{h^2}{2m\lambda^2}$ $\Rightarrow \lambda = \sqrt{\frac{h^2}{2mE}}$	**M1** **M1** **A0**
5(b)(iii)	For $E=E_{0,}$ $L = \frac{\lambda}{2}$ $L = \frac{1}{2}\sqrt{\frac{h^2}{2mE_o}}$ $= \frac{1}{2}\sqrt{\frac{(6.63\times10^{-34})^2}{2(9.11\times10^{-31})(5\times10^{-20})}}$ $= 1.10\times10^{-9}$ m	**M1** **A1**
5(b)(iv)	 Second excited state : $9Eo \Rightarrow \lambda = \sqrt{\frac{h^2}{2mE}} = ... = \frac{1}{3}\lambda_o$ Accept negative sin graph within 0 to L.	**B1**
	Max Marks	**10**

Question	Answer	Marks
6(a)(i)	Energy expenditure = 23 kWh = 23 x 1000 x 60 x 60 = 8.28×10^7 J	**M1**
6(a)(ii)	Average energy expediture per kilometer $= \frac{8.28 \times 10^7}{122}$ $= 680$ kJ km^{-1}	**M1** **A1**
6(a)(iii)	Classic model's energy expenditure $= \frac{9.70 \times 1000 \times 3600}{29.1}$ $= 1200$ kJ km^{-1}	**M1** **A1**
6(b)(i)	The electrical energy produced is only 30% of the chemical potential energy of the fossil fuel.	**B1**
6(b)(ii)	Electric model's energy expenditure $= \frac{100}{30} \times 679 = 2300$ kJ km^{-1}	**A1**
6(c)(i)	Amt of CO_2 emitted per kilometer $= \frac{23 \times \frac{601}{1000} \times 10^3}{122}$ = 113 g	**M1** **A1**
6(c)(ii)	• Classic variant has lower CO_2 emission per kilometer than the Electric variant (105 g vs 113 g). • Classic variant uses less energy per kilometer the Electric variant (1200 kJ km^{-1} vs 2300 kJ km^{-1}). • Singapore relies more on natural gas for generation of electricity, so the CO_2 emission may be lower or the yield of power generation could be higher. (any 2 points)	**A2**
6(d)(i)	Capacity $= [(20 \times 2) + 0.5(20 + 15)(1) + 0.5(15 + 4)(1) + 0.5(4)(1)]$ $= 69$ kWh Or any other methods with clear workings. [M1] : Working is unclear [A2]: full credit for answers in the +/- 1 kWh range (68–70); deduct one mark if answer outside of this range but still within +/- 3 kWh. Outside of range, no credit awarded.	**M1** **A2**
6(d)(ii)	 Same area under graph ➔ taper later [1] but end earlier [1]	**B1**
	Max Marks	**15**

Question 7 Suggested Solution

Diagram:

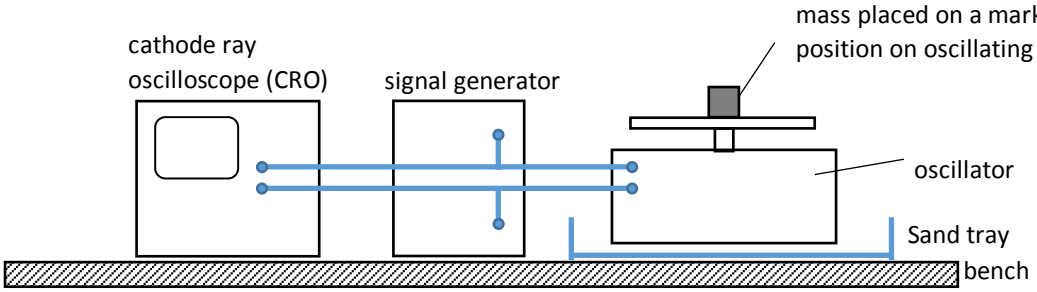


Fig 8.1

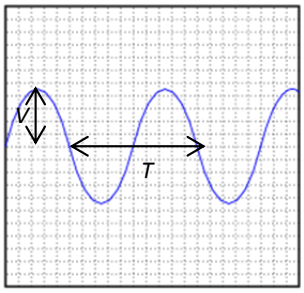


Fig 8.2

Procedure

1. Using a marker, mark a cross near the centre of the plate. Place the mass on the cross. Check that the mass is on the cross before the start of every trial.

2. Set up the apparatus as shown in Fig 8.1. Do preliminary trials to determine the appropriate mass to use such that for the range of voltage supplied by the signal generator, the mass is observed to leave the plate as the plate vibrates above a certain frequency that is within the range of the signal generator.

3. Switch on the signal generator. Adjust the amplitude so that the plate is observed to be vibrating. Adjust the Y-scale to maximise the waveform on the CRO display (Fig 8.2). Measure the amplitude of the voltage *V* by taking into account the Y-scale. Example, if the amplitude is 3.5 cm on the display and the Y-scale is 2V/div, then the amplitude is 3.5 x 2 = 7.0 V.

4. Keeping the amplitude constant, slowly increase the frequency of the signal generator until the mass starts to lose contact with the oscillating plate. This occurs when the sound of the mass falling onto the plate can be heard.

5. Measure the period of the waveform from the CRO display by multiplying the length of one cycle with the time-base. Calculate the frequency *f* using $f = \frac{1}{T}$. Record as f_1.

6. Increase the amplitude of the signal generator *V*.

Repeat steps 3 and 5 to obtain at least 8 sets of corresponding *V* and *f*.

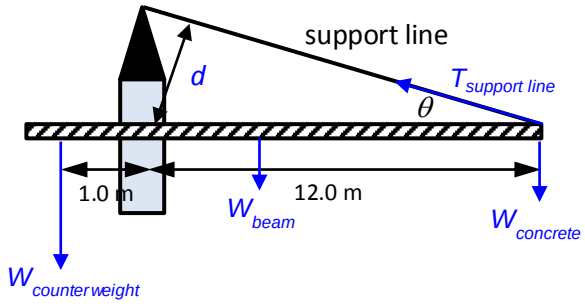
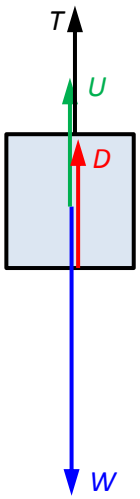
7. Starting from the last recorded *V*, repeat the experiment by decreasing the *V*. Record the corresponding frequency as f_2.

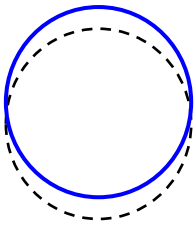
8. Calculate the average *f* for each *V* value using $f = \frac{1}{2}(f_1 + f_2)$.

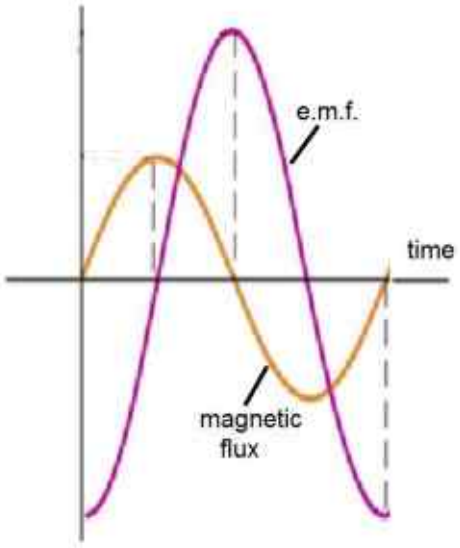
9. Suppose the relationship between *f* and *V* is given by $f = kV^n$ where *k* and *n* are constants.

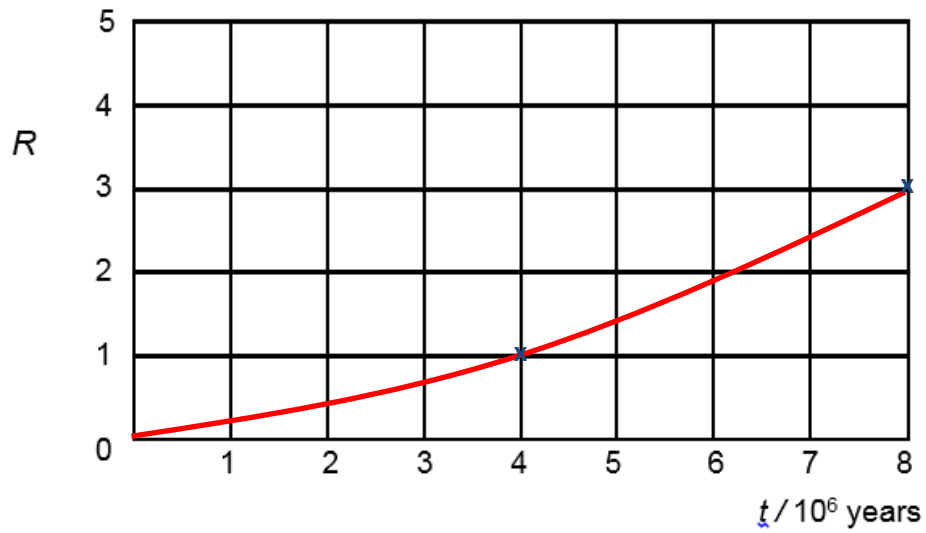
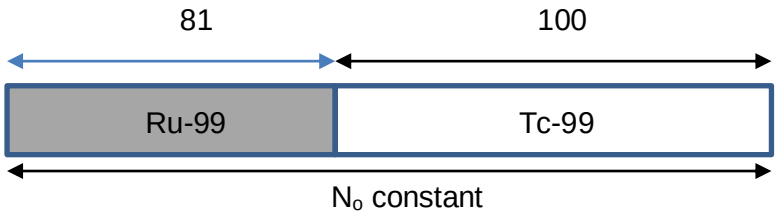
$$\Rightarrow \lg f = \lg k + n \lg V$$

10. Plot a graph of lg *f* vs. *lg V*. If the relationship is true, the plots will fall on a straight line graph where *lg k* is the y-intercept and *n* the gradient.

1	**(a)**	(i)	The **moment of a force** about a ***point*** is the product of the magnitude of the force and the perpendicular distance of the line of action of the force to the ***point***.	**B1**
		(ii)	 $\tan\theta = 3.0/12.0 \rightarrow \theta = \tan^{-1}(3.0/12.0) = 14.036^{o}$ $\sin\theta = d/12.0 \rightarrow d = 12.0\sin\theta = 12.0\sin 14.036^{o} = 2.9104$ m Taking moments about the joint, Sum of clockwise moments = sum of anticlockwise moments $(W_{concrete})(12.0) + (W_{beam})(4.0) = (W_{counterweight})(1.0) + (T_{support\ line})d$ T = 104 000 N = 104 kN	**M1** **M1** **A1**
	(b)	(i)	T = tension in the cable, acting at the top of the block U = upthrust acting on the block, acting at the centre D = drag acting on the concrete block, acting at the bottom W = weight of the concrete block, acting at the centre All arrows should be drawn with correct directions and correct points of origination. All arrows should be labelled correctly, e.g., only symbols like U or $m\ g$ are not accepted. The total length of T, U and D should be approximately equal to the length of W. Deduct one mark for every mistake. 	**A3**
		(ii)	Drag force, upthrust and weight <u>do not vary with depth</u>. As the block is lowered at constant speed, the <u>net force on it is zero</u>. Hence, the tension in the cable does not change.	**M1** **M1**

2	(a)	There are 2 wavelengths along the circumference. $2\pi r = 2\lambda \Rightarrow \lambda = \pi r$ $v = f\lambda = F\pi r$	**M1** **A1**
	(b)	A stationary wave is formed when two waves of the **same amplitude, frequency and speed** but **travelling in opposite direction** overlap with each other. The speed calculated is the **speed of the two waves** that superpose to set up the stationary wave.	**B2** **B1**
	(c)		**A1**
	(d)	The condition for stationary waves that can be set up in the glass is that the circumference must be an integer number of wavelengths. $2\pi r = \mathrm{k}\lambda = \mathrm{k}\frac{v}{f}$ where k = 1, 2, 3,... $\Rightarrow f = \mathrm{k}\left(\frac{v}{2\pi r}\right)$	**M1** **A1**
	(e)	At that mode of vibration, the **frequency of the high intensity sound** matches **one of the natural frequencies of the glass**. Hence, the glass will respond with **maximum amplitude**.	**A1** **A1**
	(f)	During resonance, it **takes time for energy to accumulate** in the mode of vibration with frequency matching that of the sound. As the amplitude of oscillation increases beyond the breaking limit of the glass, the glass will shatter.	**A1**

3	**(a)**		Faraday's Law states that the **magnitude** of the induced emf is directly **proportional** to the **rate of change of magnetic flux linkage**. Lenz's Law states that the **polarity** of the induced emf is such that it tends to produce a current that **creates a magnetic field so as to oppose the change in magnetic flux**.	**A2** **A2**
	(b)	**(i)**	 **Fig. 3.2** Magnetic flux linkage graph - Sinusoidal shape Induced e.m.f. - Correct shape (deduct if inaccurate or kinks) - Correct phase relationship with flux graph	**A1** **A1** **A1**
		(ii)	$E = NBA\omega$ $E = (400)(5 \times 10^{-5})(25 \times 10^{-4})(8.0)$ $E = 4.0 \times 10^{-4}$ V	**M1** **A1**
		(iii)	Induced current flows in an anti-clockwise direction in figure 3.1.	**A1**
		(iv)	No change in the graph. No change in the cross-sectional area means the magnetic flux at any time is the same for both cases.	**A1**

4	**(a)**	Proof by Contradiction: Suppose all the decay products are alpha particles and total number of alpha particles produced is x. $$^{238}_{92}\text{U} \rightarrow {}^{206}_{82}\text{Pb} + x\,{}^{4}_{2}\text{He}$$ For nucleon number to be conserved: $238 = 206 - 4x \Rightarrow x = 8$ For proton number to be conserved: $92 = 82 - 2x \Rightarrow x = 5$ Need 8 alpha particles to balance the total number of nucleons, but 5 alpha particles to balance the total no. of protons in the equation. Hence, it is not possible for all decay products to be alpha particles.		**M1** **A1**
	(b)	**(i)**	$^{99}_{43}\text{Tc} \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}\text{e}$	**B1**
		(ii)	The half life of a nuclide is the **<u>average</u>** **<u>time</u>** taken for the <u>original number of nuclei / activity to fall to half of its original value.</u>	**B1**
	(b)	**(iii)**	$\lambda = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{(4.00\times10^{6})} = 1.73\times10^{-7}\ \text{year}^{-1}$	**A1**
	(b)	**(iv)**	 [B1] – curves exponentially up, [B1] passing through (0,0), (4, 1) and (8,3)	**B2**
	(b)	**(v)**	 For Tc-99 at time t : $N = N_o e^{-\lambda t}$ $t = \dfrac{1}{\lambda}\ln\left(\dfrac{N_o}{N}\right)$ $= \dfrac{1}{(1.73\times10^{-7})}\ln\left(\dfrac{81+100}{100}\right)$ $= 3.43\times10^{6}$ years	**M1** **A1**

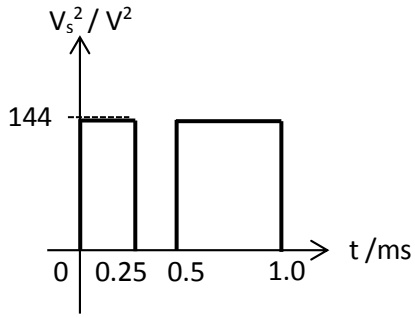
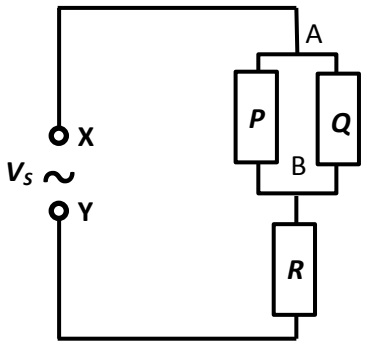
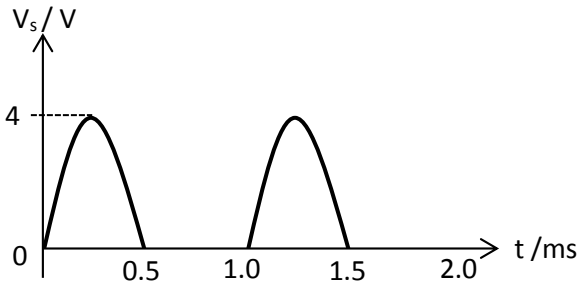
5	**(a)**	(i)	The air is initially at rest with respect to the lightcraft. Upon getting energy from the laser, it accelerates out of the lightcraft. By Newton's second law, there is a net force acting on the air. As the expanded air is being ejected from the engine, by Newton's third law, it exerts a force on the engine forward. When this force exerted by the ejected air is larger than the weight of the lightcraft, it produces an upward resultant force that accelerates the lightcraft upwards, by Newton's second law.	**B1** **B1** **B1**
		(ii)	Using $v^2 = u^2 + 2as$ $(5 \times 340)^2 = 0 + 2a(30 \times 1000)$ $a = 48.17 \text{ m s}^{-2}$ Using $F = ma$ $F = 2 \times 48.17 = 96.3 \text{ N}$	**M1** **B1** **B1**
		(iii)	Using ideal gas equation, $pv = nRT$ and assume constant volume: $P_1/T_1 = P_2/T_2$ $1.0 \times 10^5/(300) = P_2/40{,}000$ $P_2 = 13.3$ MPa	**M1** **B1**
		(iv)	At this altitude, there will little or no air/atmosphere. Thus, limited air can be heated by the laser or there will little air molecules ejected resulting in little thrust. OR Laser has diverged too much and will not be intense enough to heat up the gas.	**A1** **B1** **A1** **B1**
5	**(b)**	(i)	The internal energy of a gas is the **sum of microscopic kinetic energy due to random motion of the gas molecules** and the **microscopic potential energy due to intermolecular forces.**	**A2**
		(ii)		**A4**

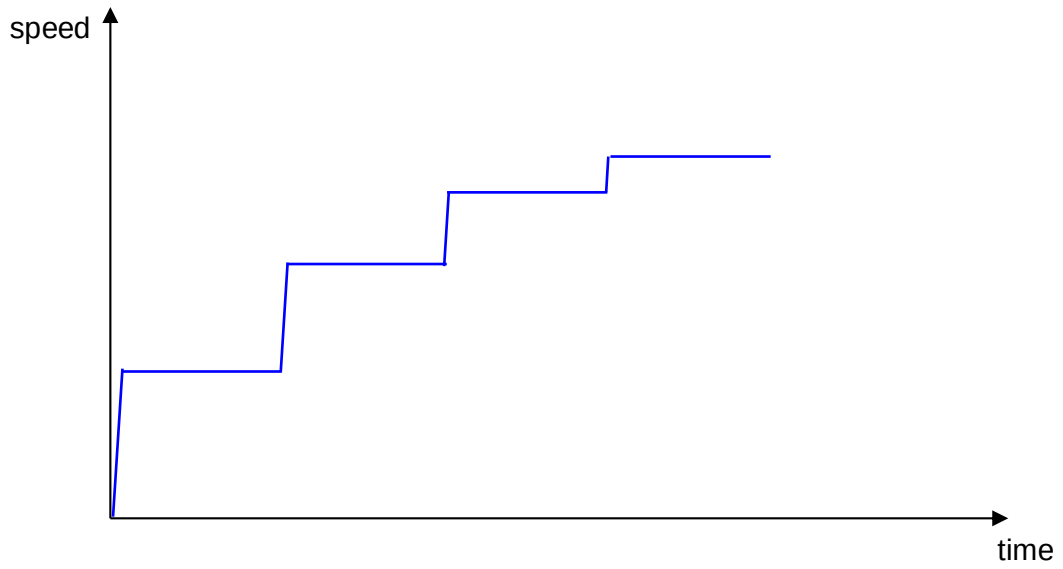
	heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B	-41.1	**41.1**	**0**
B to C	0	**47.2**	47.2
C to D	70.8	**- 70.8**	**0**
D to A	0	**- 47.2**	**- 47.2**

		(iii)	Efficiency = net work done by the gas / heat supplied to gas $= -(41.1 + 47.2 - 70.8 - 47.2) / 70.8$ = 41.9%	**M1** **B1**
		(iv)	$\Delta U = Q + W$ For the process B to C, Q = 0. $\Delta U = W$ $3/2\ Nk\Delta T = W$	**M1**

			3/2 N (1.38 x 10^{-23}) (542-300) = 47.2 N = 9.42 x 10^{21}	**B1**

6	**(a)**		Both electromotive force (e.m.f) and potential difference (p.d) refers to the energy converted per unit electric charge. E.m.f. refers to conversion of **other forms of energy to electrical energy.** This is use for devices which are supplier of electrical energy. Potential difference refers to conversion from **electrical energy to other forms of energy**.	**A1** **A1**
	(b)	**(i)**	$V_{AB} = V_{CD}$	**A1**
		(ii)	There is only one junction – junction P along AB. If current were to change, it must change at P which has 3 branches. However, the current from P to the galvanometer is zero. By conservation of charge, the current into P must be equal to current out of P. ***Alternative*** Since the current through the galvanometer is zero, AP and PB are therefore connected in series and their current must be the same.	**M1** **A1** **M1** **A1**
		(iii)	$\frac{V_{AP}}{V_{PB}} = \frac{V_{CQ}}{V_{QD}}$ or any correct combination. All four variables must be in one equation.	**A1**
		(iv)	$\frac{V_{AP}}{V_{PB}} = \frac{V_{CQ}}{V_{QD}}$ $\frac{I_{AB}R_{AP}}{I_{AB}R_{PB}} = \frac{I_{CD}R_X}{I_{CD}R_Y}$ $\frac{l_{AP}}{l_{PB}} = \frac{R_X}{R_Y}$ since resistance along the same wire is proportional to its length $\frac{60}{100-60} = \frac{30}{R_Y}$ $R_y = 20\ \Omega$	**M1** **M1** **A1**
		(v)	No change since the relationship $V_{AB} = V_{CD}$ still holds.	**A1**
		(vi)	P to Q	**A1**
		(vii)	To compare resistance. Must describe how this is done. Other practical suggestions with details of how the components are connected and used would be accepted.	**A1**

	(c)	**(i)**	Squaring the graphs and arranging the curved portion to a rectangle.  Mean square voltage = 108 V² Root-mean-square voltage = 10.39 V	**B2** **A1**
		(ii)	 	**A1**
		(iii)	Effective resistance across junctions AB = 10/2 = 5Ω Using potential divider principle, Max pd across P = $\frac{5}{10+5}(12) = 4$ V	**M1** **A1**
		(iv)	 Correct waveform for two cycles Correctly labelled axes	**A2**

7	**(a)(i)**	The magnetic field is directed out of the plane of the paper. The protons experience a magnetic force. As the magnetic force is always perpendicular to the direction of travel of the proton, the proton moves in a uniform circular motion.	**B1** **B1** **B1**
	(ii)	Magnetic force provides for centripetal force. $Bev = m\frac{v^2}{r}$ $r = \frac{mv}{Be}$	**B1** **B1** **A0**
	(iii)	$\text{time spent in one semi-circle} = \frac{0.5 \text{ x circumference}}{\text{speed}}$ $T = \frac{\pi r}{\left(\frac{mv}{Be}\right)} = \frac{\pi m}{Be}$	**M1** **A0**
	(b)(i)(1)	$r = \frac{mv}{Be}$ As the proton **accelerates** through the gap each time, its **speed increases**, hence the **radius of the circle which is proportional to the velocity** gets bigger.	**B1** **B1**
	(2)	As the **speed of the proton increases** with each time it passes through the gap, it takes **less time within the e-field** and gets **accelerated by a smaller amount**. So by $r = \frac{mv}{Be}$, the radii increase by lesser amount each time.	**B1** **B1**
	(3)	As shown in (a)(iii), the time of travel in the dee, $t = \frac{\pi m}{Be}$, is **independent of the speed** of the proton. Hence the **frequency** of the AC, *f = 1/2t*, is **also independent** of the speed of the proton.	**B1** **B1**
	(b)(ii)	 - Duration of each step constant [1] - Step-up progressively smaller with same gradient [1] - 4 steps (as asked in question) [1]	**B3**

		- Time spent within the gap should be small wrt the duration inside B-field, Vertical line also accepted as question did state the time is negligible	
	(b)(iii)	The output energy of the particle is the kinetic energy when the particle moves in the biggest semi-circle available at radius R $R = \frac{mv}{Bq}$ $v^2 = \frac{B^2q^2R^2}{m^2}$ $E = \frac{1}{2}mv^2 = \frac{B^2q^2R^2}{2m}$ 1 mark for the statement or equivalent. 2 marks for the correct manipulation to reach the expression.	**B1** **M2**
	(iv)	$E = \frac{B^2q^2R^2}{2m} = \frac{(2.0)^2(1.6\times10^{-19})^2(2.3)^2}{2(1.67\times10^{-27})} = 1.62\times10^{-10}$ J E = 1.01 x 10^3 MeV	**C1** **A1**

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9646/01

Paper 1 Multiple Choice **30 August 2016**

Additional Materials: Multiple Choice Answer Sheet **1 hour 15 minutes**

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, civics group and index number on the Answer Sheet in the spaces provided unless this has been done for you.

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 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.

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	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 In an experiment to determine the acceleration of free fall *g*, a ball bearing is held by an electromagnet. When the current to the electromagnet is switched off, a clock starts and the ball bearing falls. After falling a distance *h*, the ball bearing strikes a switch to stop the clock which measures the time of the fall, *t*.

The readings for *h* and *t* obtained by a student are as follow

$$h = (0.785 \pm 0.002) \text{ m}$$
$$t = (0.4000 \pm 0.0008) \text{ s}$$

Which row correctly states the fractional uncertainty of *g* and the physical quantity that affects the fractional uncertainty of *g* most?

	fractional uncertainty of *g*	physical quantity that affects the fractional uncertainty of *g* most
A	6.55×10^{-3}	time of fall, *t*
B	6.55×10^{-3}	distance fallen, *h*
C	1.45×10^{-3}	time of fall, *t*
D	1.45×10^{-3}	distance fallen, *h*

2 A car is travelling at its cruising speed on an expressway. It is then brought to rest.

Which value is most likely to represent the car's change of momentum?

A 3×10^3 kg m s^{-1}
B 3×10^4 kg m s^{-1}
C 3×10^5 kg m s^{-1}
D 3×10^6 kg m s^{-1}

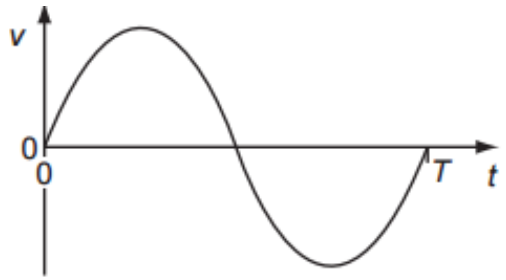
3 On a particular railway, a train driver applies the brakes of the train when passing a yellow signal which is at a distance of 1.00 km from a red signal where the train must stop.

The maximum deceleration which the train bogie can withstand is 0.215 m s^{-2}. The train can be assumed to decelerate uniformly.

Of the following options, which gives the maximum speed that the train can pass the yellow signal, and still stop safely at the red signal?

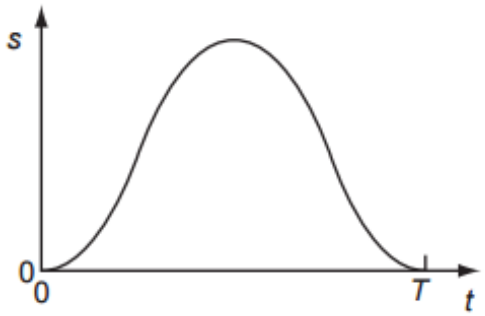
A 19.0 m s^{-1} **B** 20.0 m s^{-1} **C** 21.0 m s^{-1} **D** 440 m s^{-1}

4 The graph shows the variation of the velocity v of an object moving in a straight line with time t.

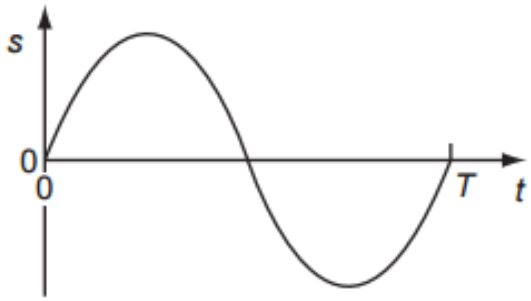


Which graph represents the displacement s of the object from $t = 0$ to $t = T$?

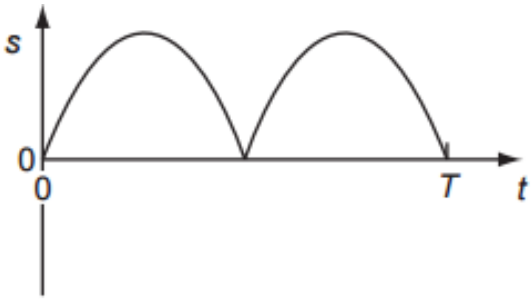
A



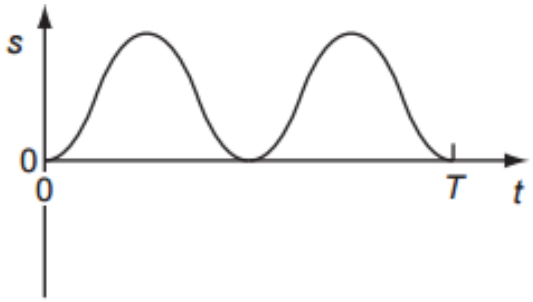
B



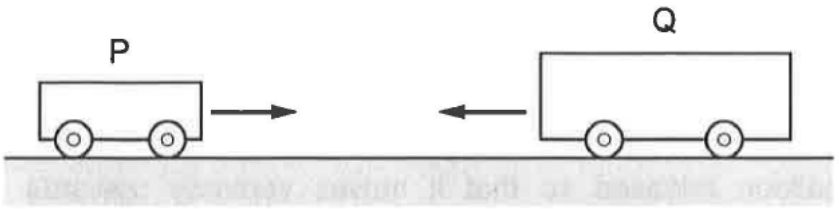
C



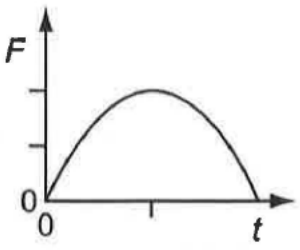
D



5 Two trolleys P and Q approach each other and collide.

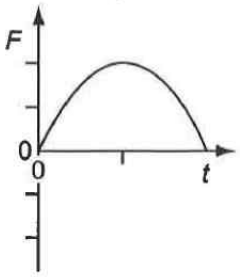


The graph shows the variation with time *t* of the force *F* of P on Q.

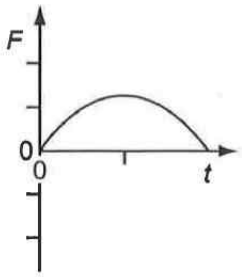


Which graph, drawn to the same scale, shows the variation with time *t* of the force *F* of Q on P?

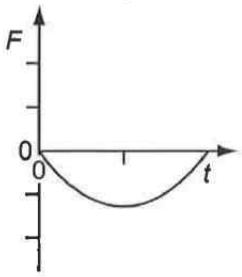
A



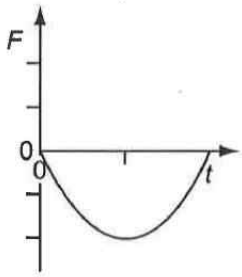
B



C



D



6 A horizontal jet of water strikes a vertical wall and flows down the wall without splashing.

Which quantity equals the magnitude of the force exerted by the jet on the wall?

A change in kinetic energy of the water per length of jet stopped

B change in momentum of the water stopped per second

C rate of loss of kinetic energy of the water

D weight of the water stopped per second

7 A cylindrical block of wood has a cross-sectional area A and weight W. It is totally immersed in water with its axis vertical. The block experiences pressures p_t and p_b at its top and bottom surfaces respectively.

Which of the following expressions is equal to the upthrust on the block?

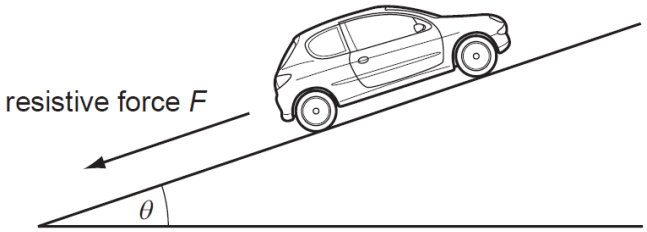
A $W-(p_b-p_t)A$

B $(p_b-p_t)A-W$

C $(p_b-p_t)A$

D (p_b-p_t)

8 A car of mass m travels at constant speed up a slope at an angle θ to the horizontal, as shown in the diagram. Air resistance and friction provide a resistive force F.



What is the driving force provided by the car's engine?

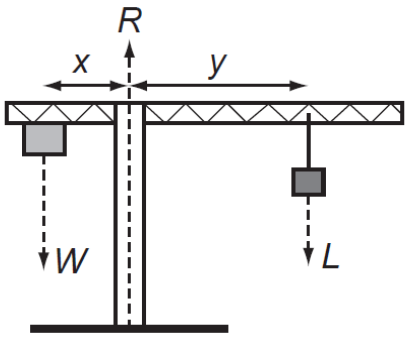
A $mg\cos\theta$

B $mg\sin\theta$

C $mg\cos\theta + F$

D $mg\sin\theta + F$

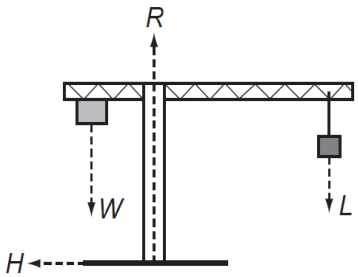
9 The diagram shows a crane supporting a load *L*.



A mass provides a balancing load *W*. The position of the loads are such that the system is perfectly balanced with $Wx = Ly$. The ground provides a reaction force *R*.

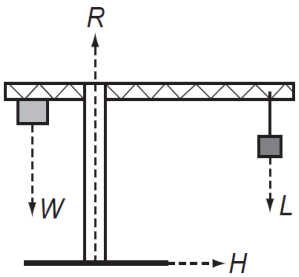
If the load *L* is moved further out so that the distance *y* increases, and the crane does not topple, which statement is correct?

A



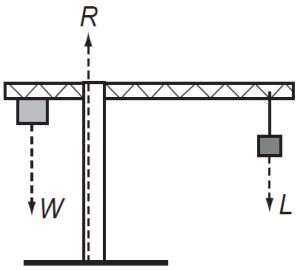
A horizontal force *H* acts on the base of the support column towards the left.

B



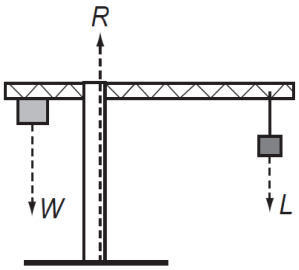
A horizontal force *H* acts on the base of the support column towards the right.

C



The reaction force *R* moves to the left.

D



The reaction force *R* moves to the right.

10 A crate is pushed 10 m along a horizontal surface by a force of 80 N. The frictional force opposing the motion is 60 N.

How much of the work done is converted into thermal energy and how much into kinetic energy of the crate?

	thermal energy / J	kinetic energy / J
A	200	600
B	200	800
C	600	200
D	600	800

11 The force resisting the motion of a car is proportional to the square of the car's speed. The magnitude of the force at a speed of 20 m s^{-1} is 800 N.

What effective power is required from the car's engine to maintain a steady speed of 40 m s^{-1}?

A 3.2 kW **B** 64 kW **C** 128 kW **D** 512 kW

12 A pendulum bob of mass 1.27 kg, and supported by a string 0.600 m long, is travelling in a vertical circle.

The linear velocity of the bob at the bottom of the circle is 5.75 m s^{-1}.

What is the tension in the string when the bob is at the top of the circle?

A 7.69 N **B** 20.1N **C** 70.0 N **D** 82.4 N

13 Which statement about a geostationary satellite is true?

A It can remain vertically above any chosen point on the Earth's surface.
B It can orbit at any height above the Earth's surface.
C It has the same angular velocity as the Earth's rotation on its axis.
D It has the same linear velocity as a person on the Earth's surface.

14 A satellite orbits a planet at a distance *r* from its centre. Its gravitational potential energy is – 3.2 MJ.

Another identical satellite orbits the planet at a distance 2*r* from its centre.

What is the sum of the kinetic energy and the gravitational potential energy of this second satellite?

A – 0.40 MJ **B** – 0.80 MJ **C** – 1.6 MJ **D** – 6.4 MJ

15 The tip of each prong of a tuning fork emitting a note of 319 Hz vibrates in simple harmonic motion with an amplitude of 0.50 mm.

What is the speed of each tip when its displacement is zero?

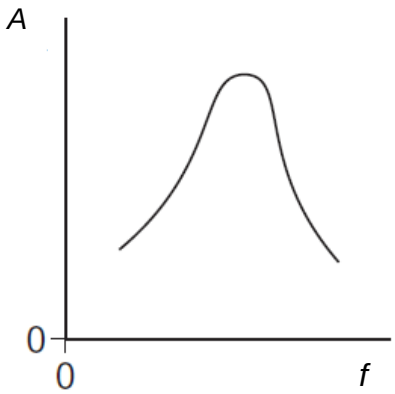
A Zero

B 1.0 mm s^{-1}

C 500 mm s^{-1}

D 1000 mm s^{-1}

16 A periodic force is applied to a lightly-damped object causing the object to oscillate. The graph shows how the amplitude *A* of the oscillations varies with the frequency *f* of the periodic force.



Which of the following statements best describe how the shape of the curve would differ if the damping had been greater?

A The curve would be lower at all frequencies.

B The curve would be higher at all frequencies.

C The curve would be unchanged except at frequencies above the resonant frequency where it would be lower.

D The curve would be unchanged except at frequencies above the resonant frequency where it would be higher.

17 In a heating experiment, energy is supplied at a constant rate to a liquid, contained in a beaker of negligible heat capacity.

The temperature of the liquid rose at 4.0 K per minute before it began to boil. It took 40 minutes from the instant the liquid started to boil, for all the liquid to boil away.

For this liquid, what is the ratio of $\frac{\text{specific latent heat of vaporisation}}{\text{specific heat capacity}}$?

A 10 K **B** 40 K **C** 160 K **D** 640 K

18 The pressure p of a gas occupying a volume V and containing N molecules of mass m each and mean square speed $<c^2>$, is given by

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

The density of argon at a pressure of 1.00 x 10^5 Pa and temperature 300 K, is 1.60 kg m^{-3}.

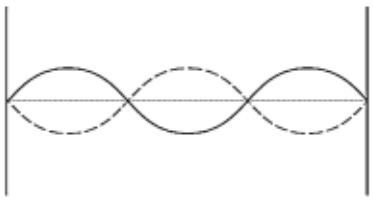
What is the root mean square speed of argon molecules at this temperature?

A 216 m s^{-1} **B** 250 m s^{-1} **C** 306 m s^{-1} **D** 433 m s^{-1}

19 The distance between two points of a progressive transverse wave having a phase difference of $\frac{\pi}{3}$ rad is 40 cm.
If the frequency of the wave is 200 Hz, what is the speed of the wave?

A 240 m s^{-1} **B** 480 m s^{-1} **C** 24 000 m s^{-1} **D** 48 000 m s^{-1}

20 A stretched string fixed at two ends is plucked in the centre and vibrates between two extreme positions as shown by the bold and dashed curves in the figure below. The horizontal dashed line is the equilibrium position.



Which one of the following statements is **false**?

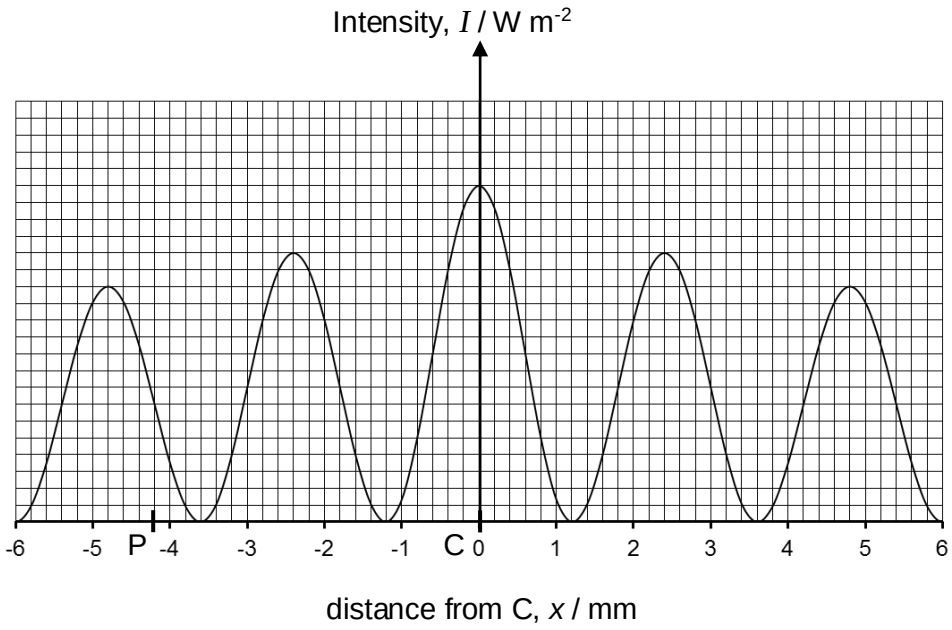
A The sound generated by the vibration is a standing longitudinal wave.

B There are four displacement nodes and three displacement antinodes.

C A transverse stationary wave is formed in the string.

D This mode of vibration is the third lowest frequency.

21 In a Young's double slit experiment, coherent monochromatic light incidents normally on a double slit. The figure below shows the variation with distance from C of the intensity I of the light on the screen. C is the central bright fringe on the screen.



If P is a point on the screen and its position is indicated in the figure above, what is the phase angle between the two waves from the double slit, when the waves meet at P?

A $\frac{\pi}{2}$ rad **B** $\frac{3\pi}{4}$ rad **C** $\frac{5\pi}{4}$ rad **D** $\frac{3\pi}{2}$ rad

22 A diffraction grating has 625 lines per mm. A beam of light incidents normally on the grating. The first order maximum makes an angle of 20° with the undeviated beam.

What is the wavelength of the incident light?

A 550 nm **B** 420 nm **C** 270 nm **D** 210 nm

23 A negative ion is projected into an electric field.

Which one of the following statements is correct?

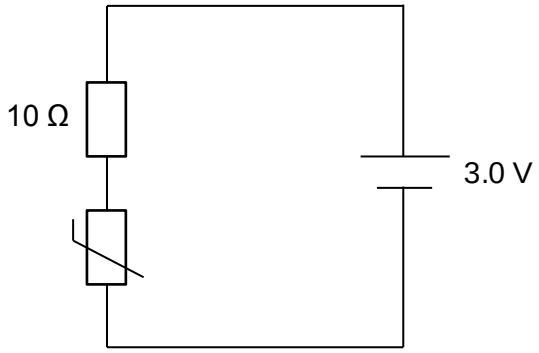
A The field can change the magnitude of the ion's velocity but not its direction.
B The field can change the direction of the ion's velocity but not its magnitude.
C The field can change both the magnitude and the direction of the ion's velocity.
D The ion will accelerate in the direction of the field.

24 Two parallel metal plates have a potential difference between them of 12 V. The distance between the plates is 1.0 mm.

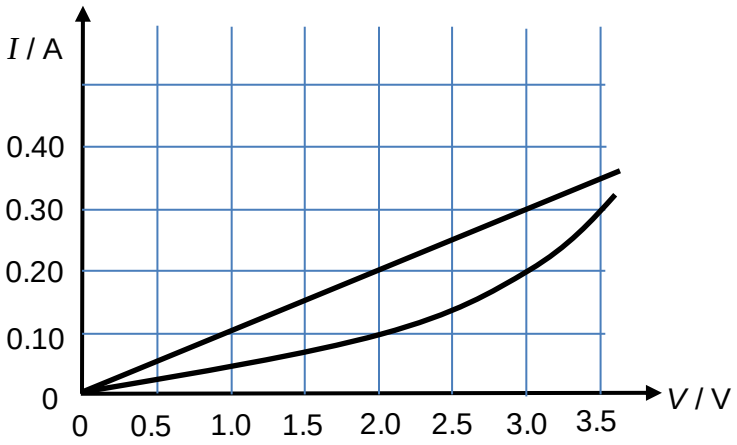
What is the electric field strength between the plates, and the work done in moving a charge of +3.9 μC from the negative plate to the positive plate?

	electric field strength / N C^{-1}	work done / J
A	12	4.7×10^{-5}
B	12	-4.7×10^{-5}
C	12 000	4.7×10^{-5}
D	12 000	-4.7×10^{-5}

25 A 10 Ω resistor and a thermistor are connected in series to a battery of e.m.f. 3.0 V and negligible internal resistance as shown in the figure below.



The graph below shows the current flowing through the thermistor and the resistor corresponding to the potential difference across them.

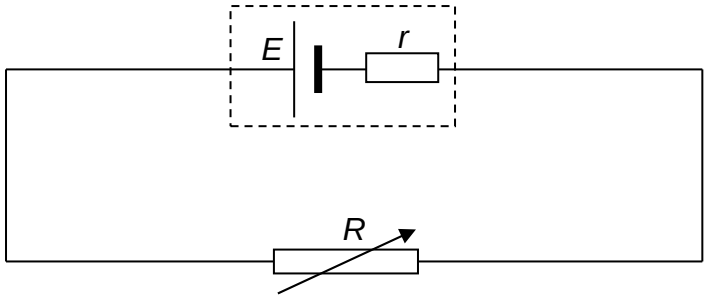


What is the current flowing through the battery in the circuit above?

A 0.10 A **B** 0.20 A **C** 0.30 A **D** 0.50 A

For questions 26 and 27, refer to the diagram below.

A battery of e.m.f *E* and internal resistance *r* is connected to a variable resistor *R* as shown below. When *R* = 16 Ω, the current in the circuit is 0.50 A. It is found that the battery supplies 4500 J of energy for a duration of 1.0×10^3 s.



26 What is the e.m.f. of the battery?

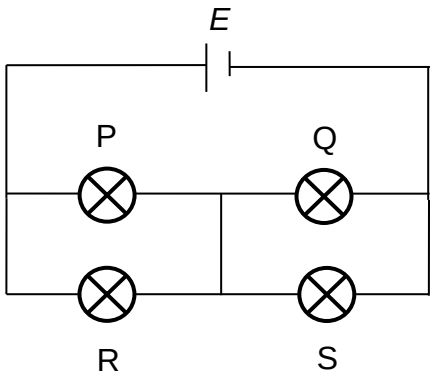
A 9.0 V **B** 10.0 V **C** 11.0 V **D** 12.0 V

27 What is the energy dissipated due to the internal resistance?

A 4.0 J **B** 4.5 J **C** 500 J **D** 4000 J

28 Four identical lamps are connected as shown below.

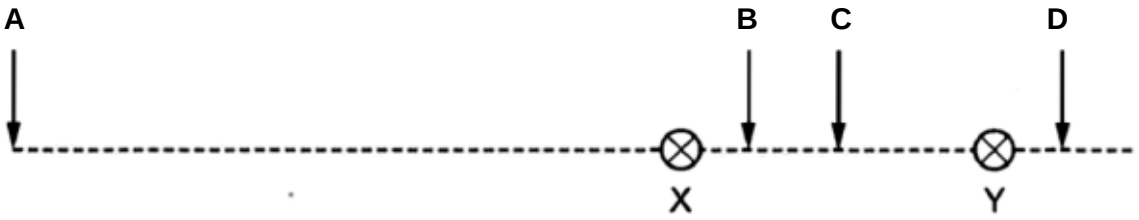
What happens when lamp P is blown out?



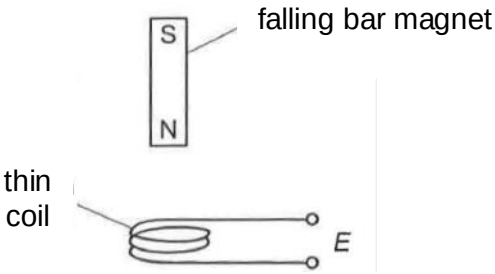
A Lamp R will not light up.
B Lamp Q and S will remain as bright as before.
C Lamp Q will become brighter than before.
D Lamp R will become brighter than before.

29 Two parallel wires X and Y carry equal currents vertically down into the paper.

At which point must a third current-carrying wire be placed so that it experiences the minimum magnetic force due to the resultant magnetic field caused by the currents in X and Y?

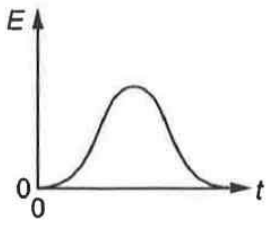


30 In an experiment to record electrical events of short duration, a student drops a bar magnet through a very thin, horizontal coil, as shown.

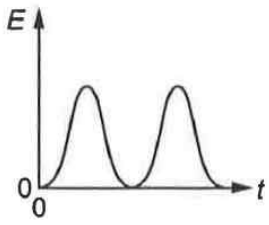


Which graph best represents how the induced e.m.f. *E* in the coil varies with time *t*?

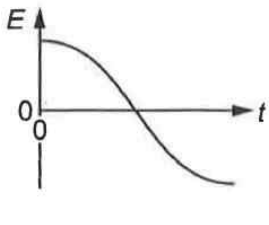
A



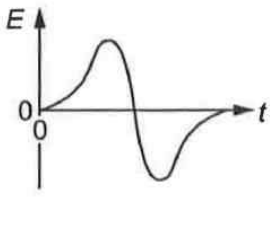
B



C

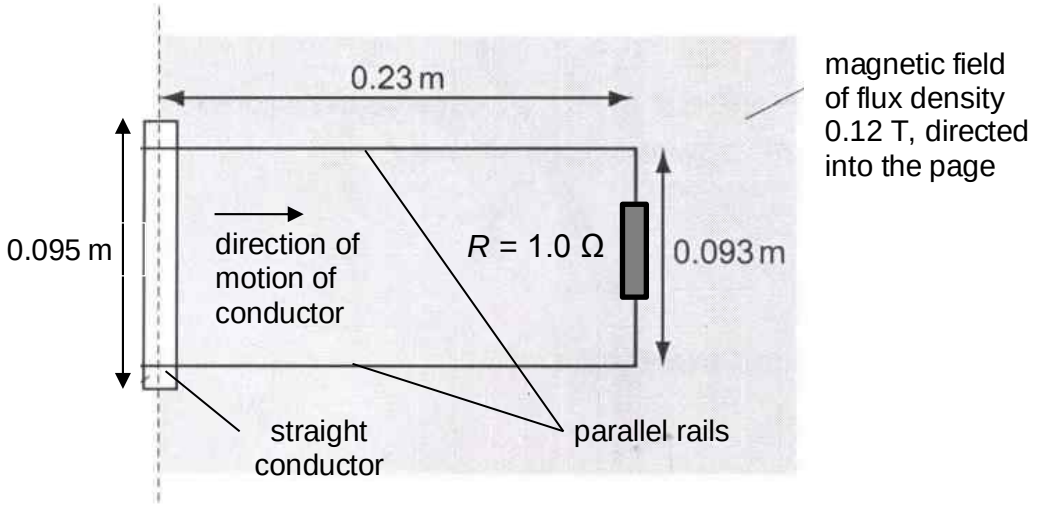


D



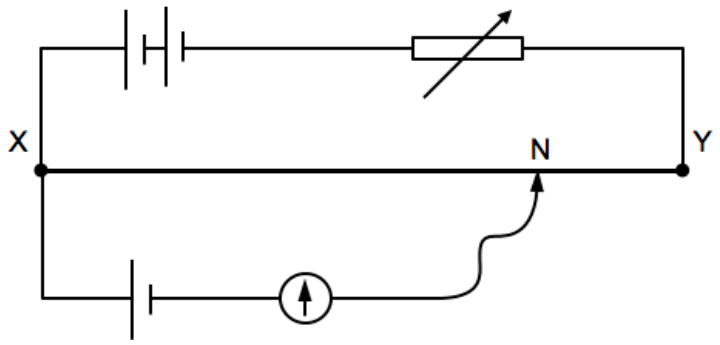
31 A straight conductor resting on two parallel rails, sweeps through a distance of 0.23 m in a uniform magnetic field in 1.00 s. The field has a flux density 0.12 T directed into the page.

Determine the magnitude and direction of the induced current flowing in the circuit.



	direction	magnitude
A	clockwise	2.57×10^{-3} A
B	clockwise	2.62×10^{-3} A
C	anti-clockwise	2.57×10^{-3} A
D	anti-clockwise	2.62×10^{-3} A

32 In the potentiometer circuit below, the moveable contact is placed at N on the bare resistance wire XY such that the galvanometer shows zero deflection.

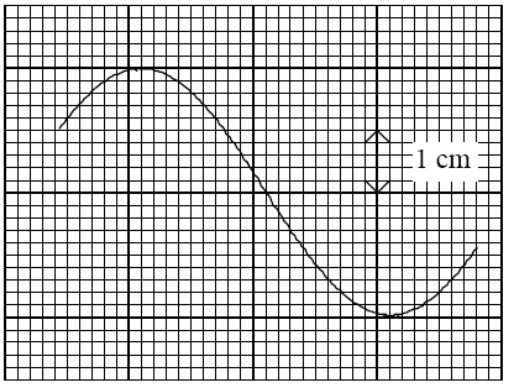


The resistance of the variable resistor is next increased.

What is the effect of increasing the resistance of the variable resistor on the potential difference across the wire XY, and on the position of the moveable contact for zero deflection on the Galvanometer?

	potential difference across XY	position of movable contact
A	increases	nearer to X
B	increases	nearer to Y
C	decreases	nearer to X
D	decreases	nearer to Y

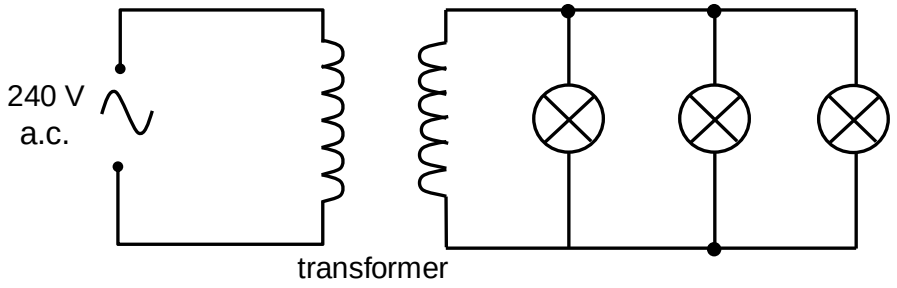
33 An alternating current passes through a resistor *R* of resistance 10 Ω. The potential difference across the resistor is measured by a C.R.O. The figure below shows the waveform on the screen. The y-sensitivity of the C.R.O. is 2.0 V cm^{-1}.



What is the average power dissipated in the resistor?

A zero **B** 0.40 W **C** 0.80 W **D** 1.6 W

34 A transformer has a 240 V a.c. input and a 12 V r.m.s. output. It is used to light three 12 V, 24 W lamps connected in parallel.



Assuming that the transformer is 100% efficient, what is the r.m.s. current in the primary circuit.

A 0.10 A **B** 0.30 A **C** 0.42 A **D** 6.0 A

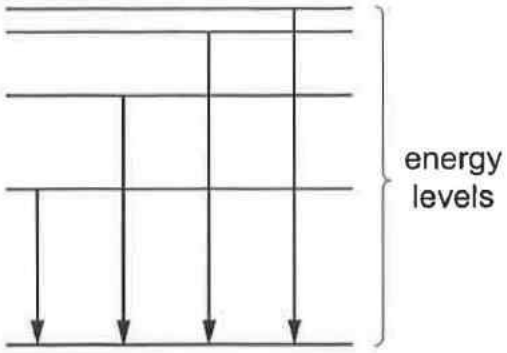
35 When an atom absorbs radiation of wavelength λ_1, it makes a transition from its ground state of energy E_1 to an excited state of energy E_3.

The atom then makes a second transition to a state of lower energy E_2, emitting radiation of wavelength λ_2.

What is the wavelength of the radiation emitted by the atom when it makes a third transition from its intermediate state of energy E_2 back to the ground state?

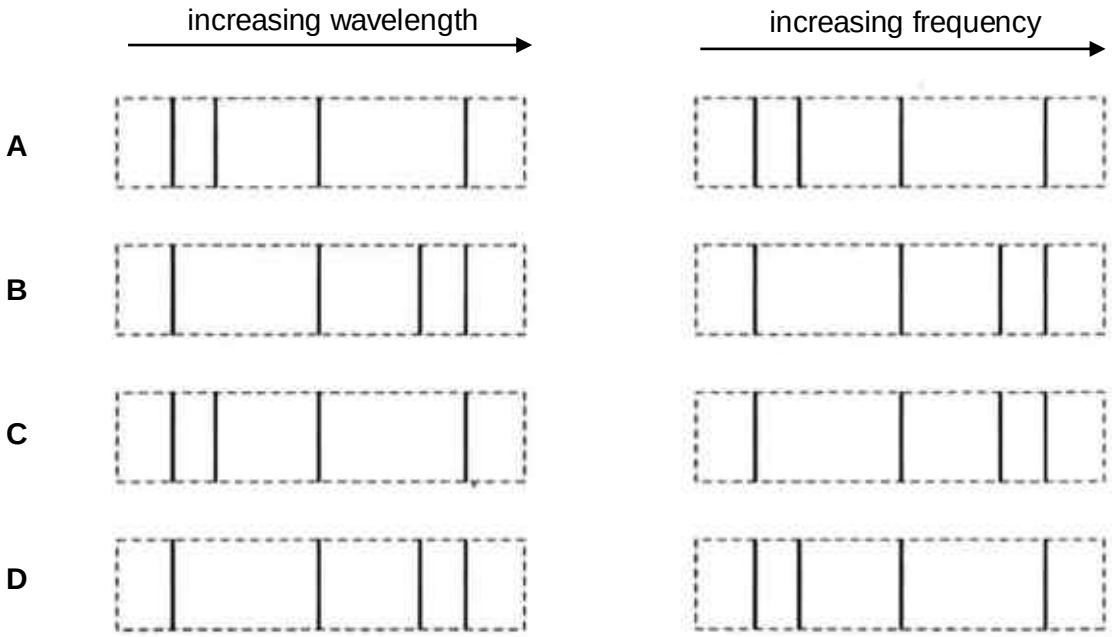
A $\lambda_1 - \lambda_2$ **B** $\lambda_2 - \lambda_1$ **C** $\frac{\lambda_1\lambda_2}{\lambda_1 - \lambda_2}$ **D** $\frac{\lambda_1\lambda_2}{\lambda_2 - \lambda_1}$

36 The diagram shows five electron energy levels in an atom and some transitions between them.



The line spectrum is in the visible spectrum and can be represented on a wavelength scale or a frequency scale.

Which diagram could represent the light emitted by the four transitions shown above?



37 The energy level schemes of possible laser materials are shown in the four options below.

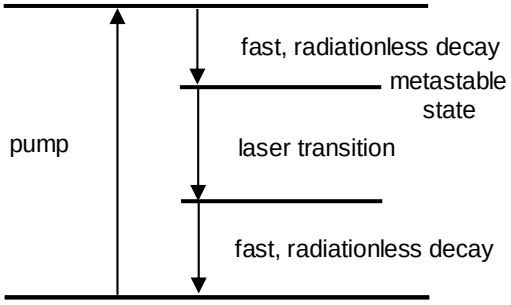
The "pump" refers to the excitation of the ground state atoms in the material.

The "fast, radiationless decay" refers to the de-excitation of an excited atom in which energy is transferred to the surrounding atoms as vibrational energy, without a photon produced.

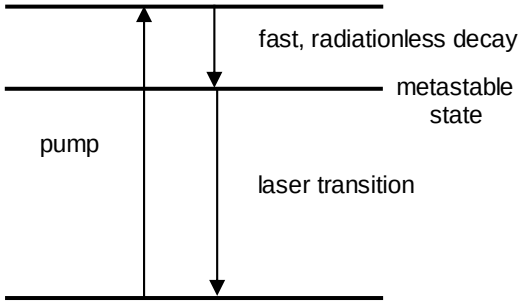
The "laser transition" refers to the de-excitation of an excited atom in which the desired laser photon is produced.

Which of the following energy level schemes best enable population inversion?

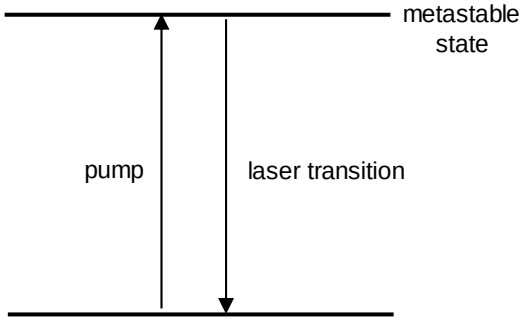
A



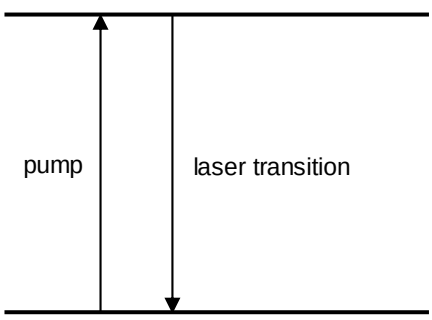
B



C

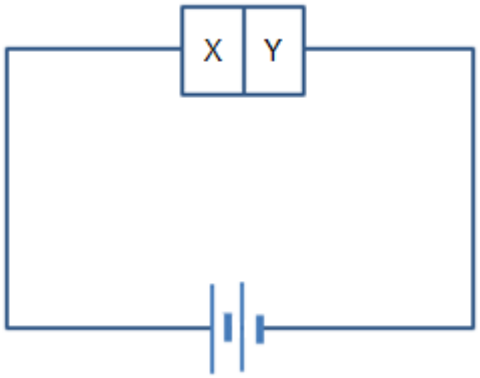


D



38 A semiconductor X is made by doping germanium crystal with arsenic (donor). Another semiconductor Y is made by doping germanium with indium (acceptor).

The two extrinsic semiconductors are next joined end-to-end, and connected to a battery as shown in the diagram below.



Which of the following statements is correct?

A X is p-type, Y is n-type and the battery is connected in forward bias.
B X is n-type, Y is p-type and the battery is connected in forward bias.
C X is p-type, Y is n-type and the battery is connected in reverse bias.
D X is n-type, Y is p-type and the battery is connected in reverse bias.

39 When α - particles are directed at a thin gold foil, it was observed that:

1. almost all the α - particles passed through the foil without deflection,

2. a few α - particles were deflected by large angles.

Which of the following best explains these observations?

	observation 1	observation 2
A	Most α - particles miss all the gold atoms.	A few α - particles bounced off the gold atoms.
B	The gold nucleus is very small so most α - particles missed all the gold nuclei.	Occasionally, the path of an α - particle approaches a gold nucleus sufficiently close to be deflected significantly.
C	Most α - particles had enough energy to pass straight through the gold foil.	Gold is very dense so the α - particles with low energy rebounded from the gold atoms.
D	The positive charge in an atom is distributed uniformly throughout the atom; it is not concentrated enough to deflect an α - particle.	Occasionally an α - particle experiences many small deflections in the same direction.

40 The nuclide Rn_{86}^{222} decays in a sequence of stages to form the nuclide Pb_{82}^{206}. Four of the nuclides formed in the sequence are α- particle emitters. The others are β- particle emitters.

How many nuclides formed in the decay sequence are β-particle emitters?

A 0 **B** 1 **C** 2 **D** 4

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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 9646/02

Paper 2 Structured Questions **19 August 2016**

1 hour 45 minutes

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 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.

Answer **all** questions.

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	
1	/11
2	/7
3	/9
4	/11
5	/7
6	/15
7	/12
Significant Figures	
Total	/72

This document consists of **20** printed pages.

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}
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	$= p\Delta V$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
hydrostatic pressure,	p	$= \rho gh$
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	$= v_o \cos \omega t$
		$= \pm\omega\sqrt{\left(x_o^2 - x^2\right)}$
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	$= x_o \sin\omega t$
transmission coefficient	T	$= \exp(-2kd)$
	where k	$= \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{½}}$

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1 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. 1.1.

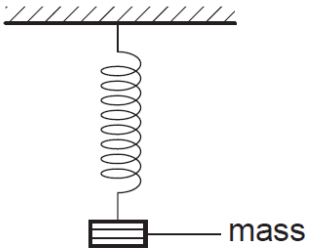

Fig. 1.1

(a) The mass is in translational equilibrium. Explain, with reference to the forces acting on the mass, what is meant by translational equilibrium.

……

……

…… [2]

(b) The mass is pulled down and then released at time $t = 0$. The mass oscillates up and down. The variation with t of the displacement of the mass d is shown in Fig. 1.2.

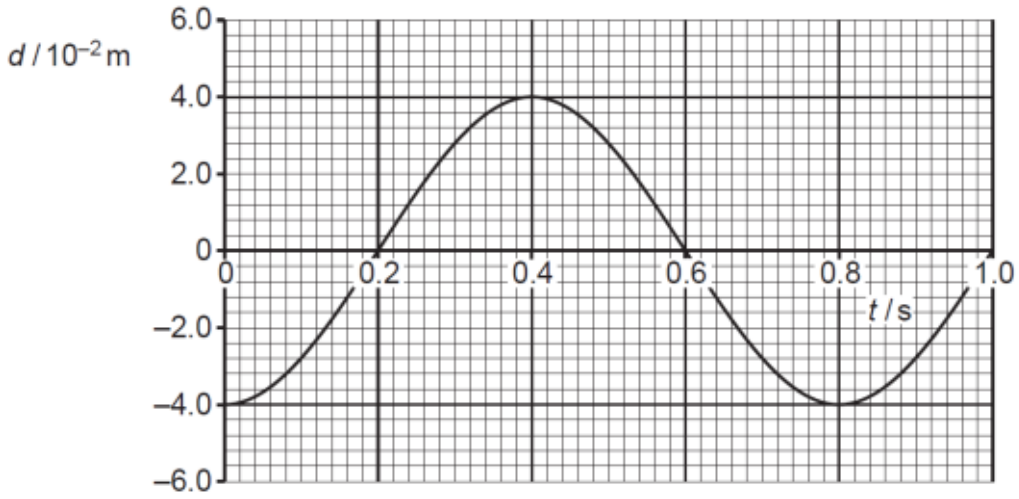

Fig. 1.2

Using Fig. 1.2, state an instant when

(i) the elastic potential energy stored in the spring is a maximum,

time = …… s [1]

(ii) the mass is in equilibrium.

time = …… s [1]

(c) The arrangement shown in Fig. 1.3 is used to determine the length l of a spring when different masses M are attached to it.

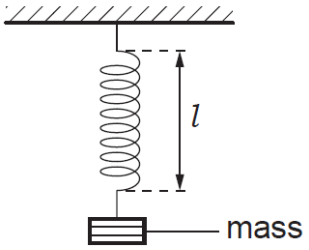

Fig. 1.3

The variation with mass M of l is shown in Fig. 1.4 below.

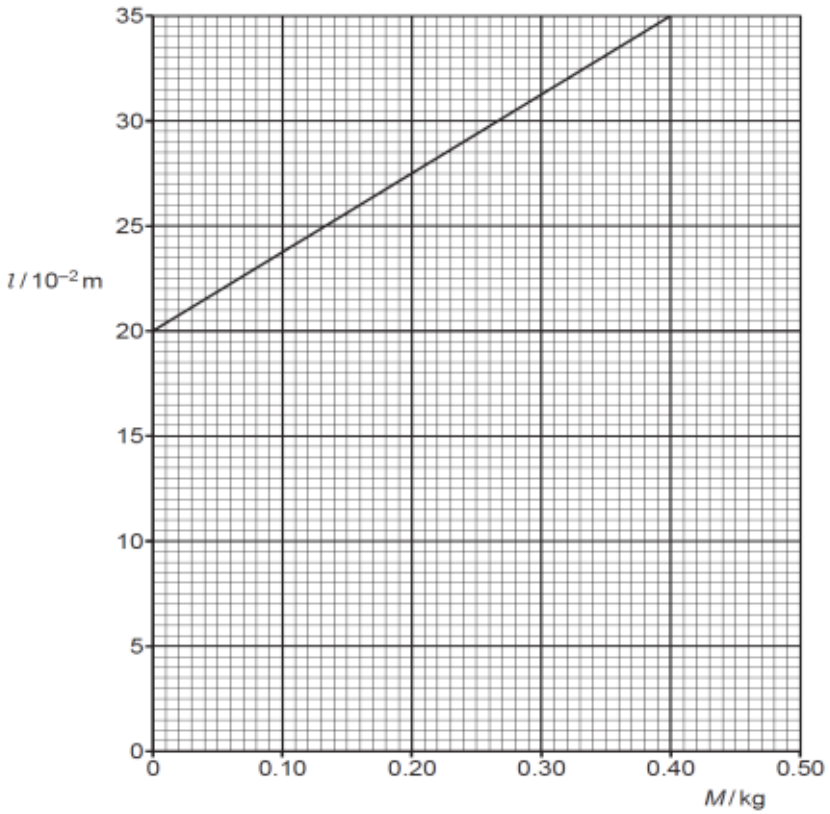

Fig. 1.4

(i) State and explain whether the spring obeys Hooke's law.

……

……

…… [2]

(ii) Show that the spring constant of the spring is 26 N m^{-1}. [2]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

energy = …… J [3]

2 **(a)** State the first law of thermodynamics.

……

……

…… [1]

(b) During the first part of the power stroke in a diesel engine, the pressure of the burning gas remains constant at 8.00×10^6 Pa, while the volume of the gas increases from 3.00×10^{-5} m^3 to 7.10×10^{-5} m^3.

(i) Calculate the work done on the gas during the first part of the power stroke.

work done on gas = …… J [2]

(ii) While this expansion is taking place, the temperature of the gas rises by 900 K. The mass of the gas is 1.27×10^{-3} kg and its specific heat capacity at constant pressure is 1.004×10^3 J kg^{-1} K^{-1}. The gas is diatomic.

Calculate the heat gained by the burning gas.

heat gained = …… J [1]

(iii) Hence find the increase in internal energy during the first part of the power stroke in the diesel engine.

increase in internal energy = …… J [1]

(iv) The gas subsequently undergoes the following processes:

1. second part of the power stroke being an adiabatic expansion from 7.10×10^{-5} m^3 to 9.00×10^{-5} m^3.

2. third part of the power stroke being an isothermal compression from 9.00×10^{-5} m^3 back to its original starting state at 3.00×10^{-5} m^3.

Sketch and label, in Fig. 2.1 below, all three parts of the power stroke in the diesel engine. The starting point of the power stroke, point A, has been drawn for you.

[2]

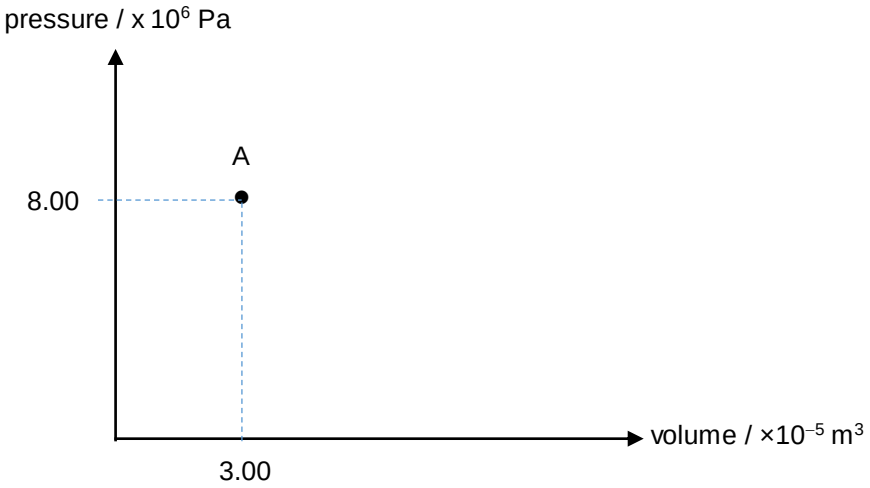

Fig. 2.1

3 **(a)** **(i)** Define the electromotive force of a cell.

……

……

…… [1]

(ii) Explain why the terminal potential difference of a cell is usually smaller than its electromotive force.

……

……

…… [1]

(b) Fig. 3.1 shows a circuit containing a cell and four resistors.

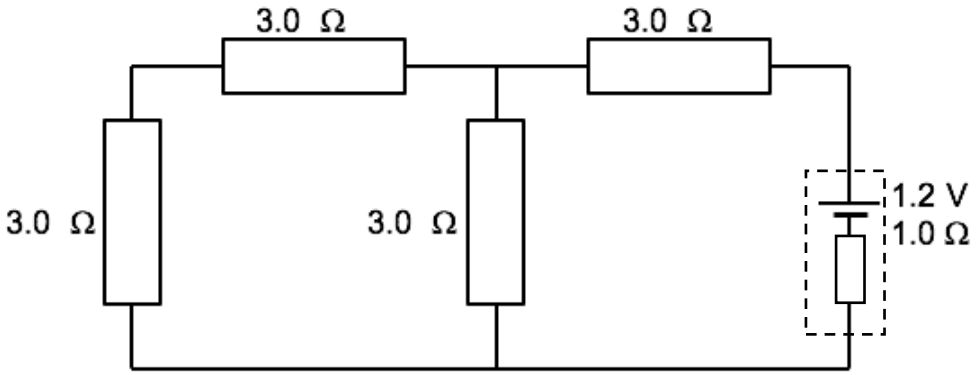

Fig. 3.1

Calculate

(i) the current through the 1.2 V cell,

current = …… A [2]

(ii) the terminal p.d. of the 1.2 V cell,

terminal p.d. = …… V [1]

(iii) the efficiency of the circuit.

efficiency = …… % [1]

(c) Fig. 3.2 below shows 2 coils X and Y wound on a soft iron core.

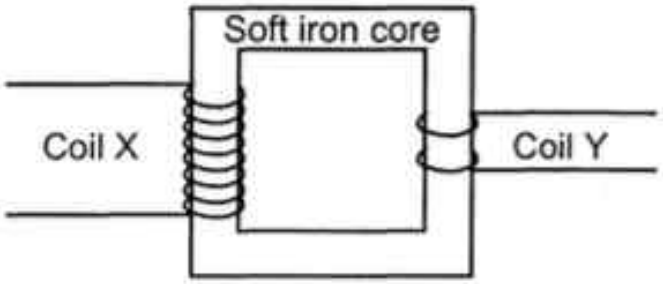

Fig. 3.2

The inputs of coil X is now connected to a 240 V mains supply, where the current changes directions 100 times per second. The output of coil Y is connected to a 12 V, 3.0 A light bulb, the bulb is working normally.

(i) Assuming that the efficiency of the transformer is 90%, make use of energy considerations to calculate the current in coil X.

current = …… A [2]

(ii) Suggest one reason why the transformer is not 100% efficient.

……

…… [1]

4 **(a)** State the laws of electromagnetic induction.

……

……

……

…… [2]

(b) **(i)** A solenoid is connected in series with a resistor, as shown in Fig. 4.1.

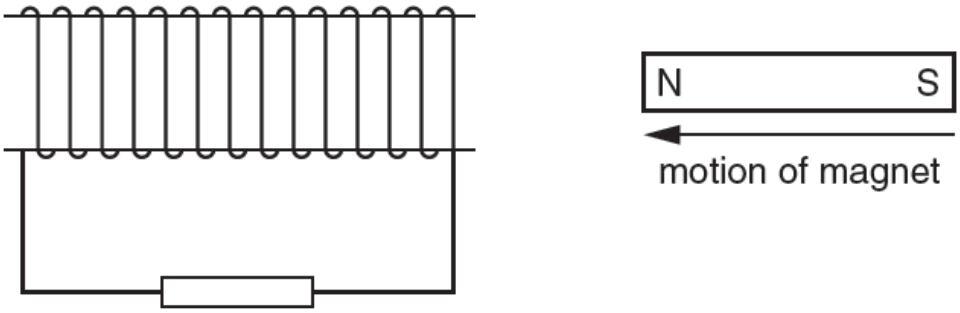

Fig. 4.1

As the magnet is being moved into the solenoid, thermal energy is generated in the resistor.

Use the laws of electromagnetic induction to explain the origin of this thermal energy.

……

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…… [4]

(ii) Draw in Fig. 4.1. the direction of the induced current in the solenoid. [1]

(c) Explain why the alternating current in the primary coil of a transformer is not in phase with the alternating e.m.f. induced in the secondary coil.

……

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…… [4]

5 **(a)** Explain, using band theory, why the conductivity of an intrinsic semiconductor increases when temperature increases.

……...

……...

……...

……..…… [2]

(b) Explain why the conductivity of a metal decreases when temperature increases.

……...

……...

……...

……..…… [2]

(c) **(i)** Explain, using band theory, how the introduction of small amounts of Group 5 impurities to intrinsic semiconductors improves their conductivities.

……

……

……

……..… [2]

(ii) However, when too many impurity atoms are introduced, as in the case of highly-doped semiconductors, the resistance of the semiconductor actually increases, rather than decrease, when temperature increases.

With reference to your answer to **(b)**, suggest a reason for this behavior of highly-doped semiconductors.

……

……

…… [1]

6 A scintillation counter is an instrument that detects and measures high energy charged particles. A scintillation counter comprises three main components i.e.

Component 1: Scintillator material
Component 2: Photocathode
Component 3: Photomultiplier tube

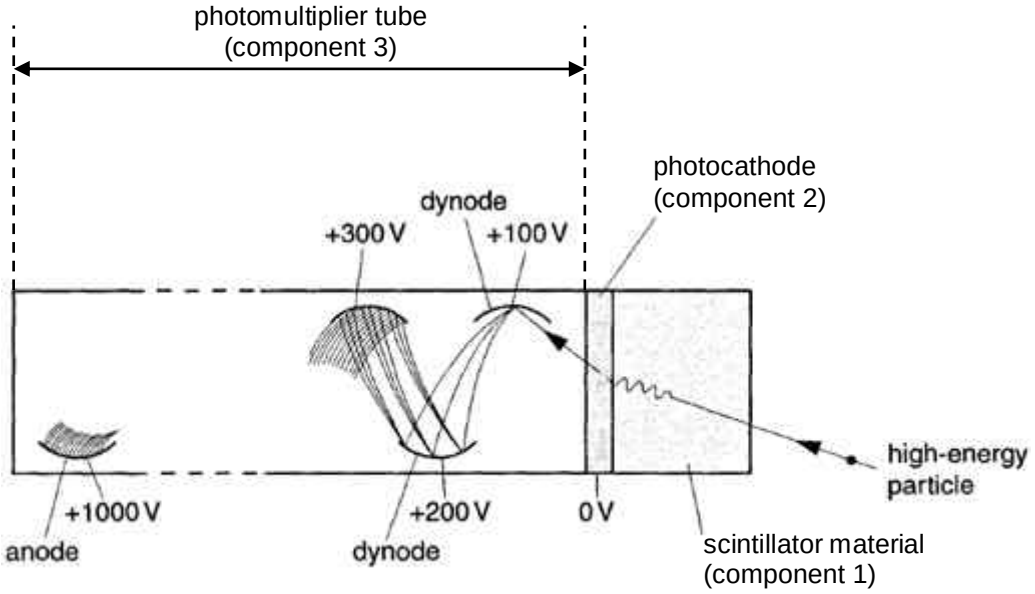

Fig 6.1

(a) In the scintillator material (component 1), high energy particles interact with the material to produce photons.

In one particular experiment, high energy particles produce 90 nW of light of wavelength 400 nm in the scintillator material.

(i) Calculate the energy, E_p, of a single photon of wavelength 400 nm.

E_p = ... J [1]

(ii) Show that the rate of photons produced in the scintillator, n_p, is 1.81×10^{11} s^{-1} .

[1]

(b) When the photons produced in the scintillator material (component 1) reaches the photocathode (component 2), the photons eject some of the surface electrons due to the photoelectric effect.

Radiant sensitivity, S, is defined as the photoelectric current generated by the photocathode divided by the incident radiant flux, ϕ of the incoming photons from the scintillator material.

S is expressed in units of amperes per watts (A W^{-1}).

(i) Starting from the definition of radiant sensitivity and/ or examining its units, show that radiant sensitivity, S, is given by:

$$S = \frac{n_e e \lambda}{n_p h c}$$

where n_e is the rate of emission of photoelectrons and n_p is the rate of photons produced in the scintillator material.

Show your working clearly.

[1]

(ii) Quantum efficiency, η, is defined as the number of photoelectrons emitted, N_e, from the photocathode divided by the number of incident photons, N_p.

$$\eta = \frac{N_e}{N_p}$$

Quantum efficiency can also be calculated from the radiant sensitivity, S, of the photocathode.

Using the expression for S in **b(i)** or otherwise, show that the quantum efficiency, η, can be expressed as:

$$\eta = 1.24 \times 10^{-6} \frac{S}{\lambda}$$

[2]

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(c) Fig. 6.2 shows the variation of the radiant sensitivity, *S* with the wavelength of the incident photons, for various types of photocathodes.

The graph uses a logarithmic scale.

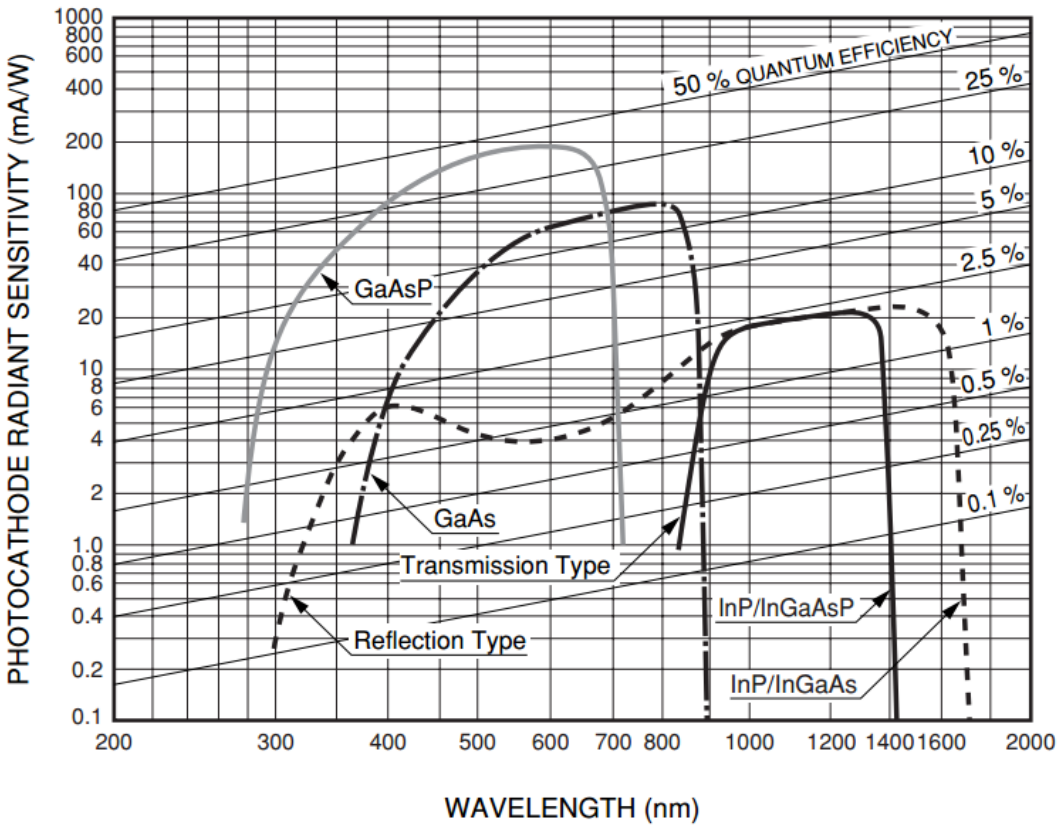

Fig. 6.2

In the experiment detailed in **(a)**, the Gallium Arsenide Phosphide (GaAsP) photocathode was used in the scintillation counter.

(i) Using Fig. 6.2, state and explain which photocathode would not have been suitable for use in the experiment.

……

……

……

…… [2]

(ii) Using values from Fig. 6.2, determine the rate of emission of photoelectrons, n_e from the GaAsP photocathode in the experiment detailed in **(a)**.

n_e = ... s^{-1} [3]

(d) In the photomultiplier tube (component 3), the photoelectrons emitted from the photocathode are accelerated towards the first positive dynode because of the 100 V potential difference between the dynode and the photocathode.

The kinetic energy of the electron is sufficient to eject, on average, 3 'secondary' electrons from the dynode. These electrons are then accelerated towards the next dynode and the whole process is repeated.

Eventually a tiny pulse of charge is detected at the anode in the photomultiplier tube and measured as the anode current.

(i) The work function energy of the photocathode material is 3.5×10^{-19} J .

Calculate the maximum kinetic energy of the photoelectrons just ejected from the photocathode due to the photoelectric effect.

maximum kinetic energy of electron = ... J [2]

(ii) For a photomultiplier with 10 dynodes, show that the number of electrons arriving at the anode for **each** photoelectron emitted from the cathode is 3^9 .

Explain your working.

[1]

(iii) Determine the current detected by the photomultiplier tube's anode.

current = …… A [2]

7 The efficiency η of a glowing filament may be expressed as

$$\eta = \frac{\text{light energy emitted in the visible range}}{\text{electrical energy input}}$$

As light energy emitted in the visible range can be difficult to measure, the efficiency could instead be determined by measuring the amount of wasted energy produced by the filament in the form of thermal energy. The efficiency is subsequently calculated using

$$\eta = 1 - \frac{\text{thermal energy}}{\text{electrical energy input}}$$

The efficiency is thought to depend on the temperature, *T* of the filament. The relationship between the efficiency and the temperature may be written in the form:

$$\eta = aT^b$$

where *a* and *b* are constants.

You are provided with a filament, a beaker with water that is to be used in the determination of the thermal energy produced by the glowing filament, and an infrared thermometer. You may also use any of the other equipment usually found in a physics laboratory.

Design an experiment to determine the relationship between η and T.

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 η and *T* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

…….

…….

…….

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9646/03

Paper 3 Longer Structured Questions **25 August 2016**

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 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 any **two** questions.

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.

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1	/7
2	/9
3	/7
4	/7
5	/10
6	/20
7	/20
8	/20
Significant Figures	
Total	/**80**

This document consists of **22** printed pages.

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
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permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
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acceleration of free fall,	g	$= 9.81$ m s^{-2}

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velocity of particle in s.h.m.	v	$= v_o \cos \omega t$
		$= \pm\omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
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	$= x_o \sin\omega t$
transmission coefficient	T	$\propto \exp(-2kd)$
	where k	$= \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{\frac{1}{2}}}$

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Section A

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

1 An Olympic ski jumper skis down a slope and launches off a cliff, landing on the ground a short time later. The mass of the ski jumper and his equipment is 80 kg.

Fig. 1.1 below shows the ski jumper just before he leaves the slope with a velocity of 20 m s^{-1} in the horizontal direction.

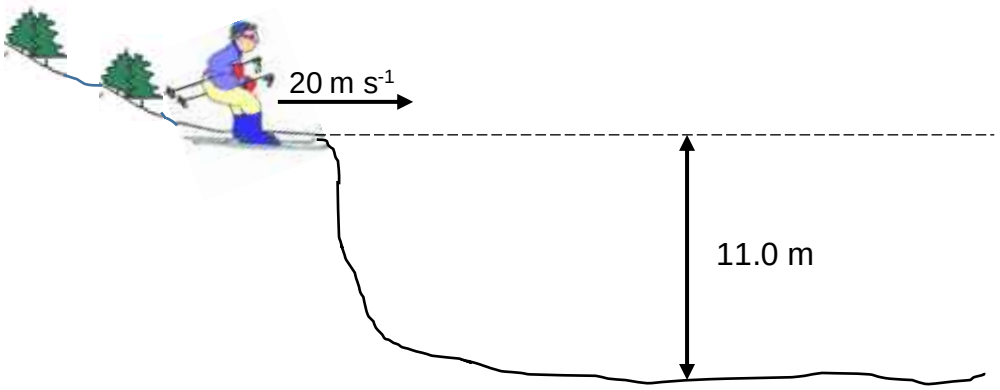

Fig 1.1

The ski jumper falls through a vertical distance of 11.0 m before landing on the ground.

(a) Calculate

(i) the time of flight of the ski jumper,

time of flight = …….. s [1]

(ii) the horizontal distance travelled by the ski jumper during this time,

horizontal distance = …….. m [1]

For Examiner's Use

(iii) the velocity of the ski jumper just before he lands.

velocity = …… m s^{-1} [2]

direction: …… ^{o} below the horizontal [1]

(b) By considering Newton's 2nd Law, explain how the snow covering the ground enables the ski jumper to land safely despite the high landing speed.

……

……

……

…… [2]

For Examiner's Use

2 **(a)** State Newton's law of gravitation.

……..

……..

…… [1]

(b) The Earth and the Moon may be considered to be isolated in space with their masses concentrated at their centres.

The orbit of the Moon around the Earth is circular, with a radius of 3.84×10^5 km. The period of the orbit is 27.3 days.

Show that

(i) the angular speed of the Moon in its orbit around the Earth is 2.66×10^{-6} rad s^{-1}.

[1]

(ii) the mass of the Earth is 6.0×10^{24} kg.

[2]

(c) The mass of the Moon is 7.4×10^{22} kg.

(i) Using data from **(b)**, determine the gravitational force between the Earth and the Moon.

force = …… N [2]

For Examiner's Use

(ii) Tidal action on the Earth's surface causes the radius of the Moon's orbit to increase by 4.0 cm each year.

Using your answer to **(c)(i)**, determine the change of the Moon's gravitational potential energy in one year.

Explain your working.

change in Moon's gravitational potential energy = …… J [3]

For Examiner's Use

3 **(a)** A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by *simple harmonic motion*.

.....

.....

..... [2]

(b) The length of a pendulum l is measured to be 30.0 cm. The angular frequency of the simple pendulum is given by $\sqrt{\frac{g}{l}}$, where g is the acceleration of free fall. Determine the period of this simple pendulum.

period = ... s [2]

(c) A simple pendulum of period 1.90 s is set up alongside another pendulum of period 2.00 s. Both pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase.

time interval = ... s [3]

For Examiner's Use

4 A long rope is held under tension between two points A and B. Point A is made to oscillate vertically and a wave is sent down the rope towards B as shown in Fig. 4.1.

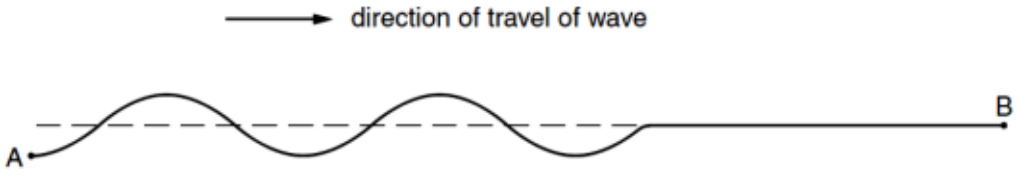

Fig. 4.1

The time for one oscillation of point A on the rope is 0.20 s. The point A moves a total distance of 80 mm during one oscillation. The wave on the rope has a wavelength of 1.5 m.

(a) **(i)** Explain the term *displacement* for a particle in the wave, on the rope.

.....

..... [1]

(ii) Calculate, for the wave on the rope,

1. the amplitude,

amplitude = …….. mm [1]

2. the speed.

speed = …….. m s^{-1} [2]

(b) Draw on Fig.4.1, the wave pattern on the rope at a time 0.050 s later than that shown.

[1]

For Examiner's Use

(c) State and explain, whether the wave on the rope is

(i) progressive or stationary,

……

…….. [1]

(ii) longitudinal or transverse.

……

…….. [1]

For Examiner's Use

5 **(a)** Fig. 5.1 below shows a filament lamp emitting white light, and is surrounded by a region of cooler helium gas.

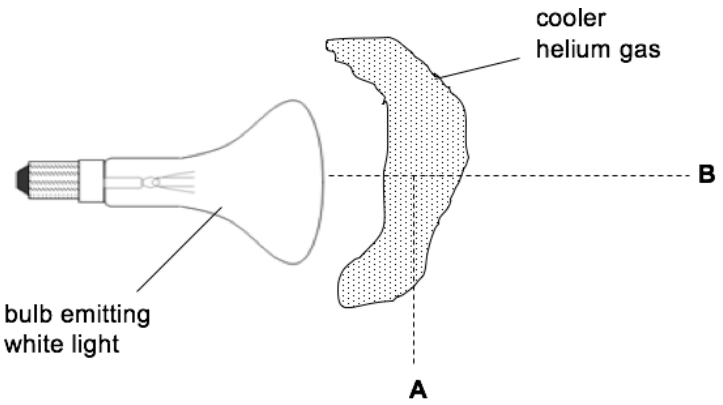

Fig. 5.1

(i) State if a helium *absorption* or *emission* spectrum is observed from

1. point A,

……... [1]

2. point B.

……... [1]

(ii) Explain the formation of the helium spectrum observed from point A.

……..

……..

……..

……..

……... [2]

(b) Fig. 5.2 shows some of the energy levels of an isolated helium atom.

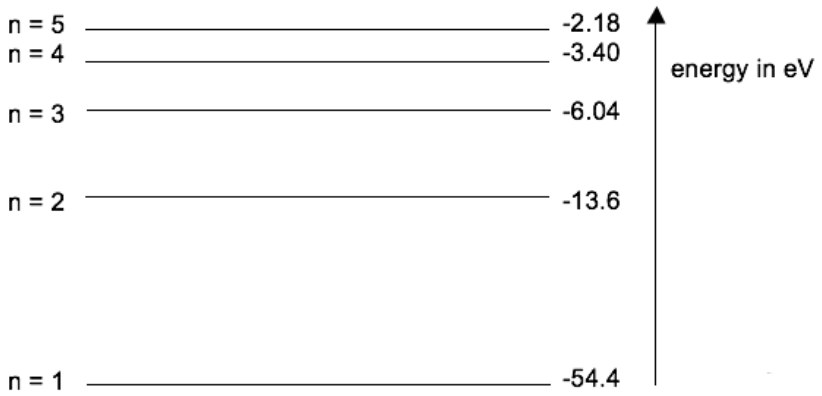

Fig. 5.2

For Examiner's Use

An electron with a kinetic energy of 50 eV collides inelastically with a helium atom in the ground state.

(i) Draw, in Fig. 5.2, the possible downward transitions of the excited helium atom following this collision.

[2]

(ii) Calculate the shortest wavelength of the radiation that is emitted from the transitions in **(b)(i).**

wavelength = ……. m [1]

(iii) Hence state the type of radiation for the wavelength calculated in **(b)(ii).**

……... [1]

(iv) Explain what happens if UV photons of energy of 50 eV had been used to excite the ground state helium atoms instead 50 eV electrons.

……..

……..

……..

…….. [2]

Section B

For Examiner's Use

Answer **two** questions in this section.

6 **(a)** State Coulomb's law in electrostatics.

……

……

…… [1]

(b) Fig. 6.1 shows two identical conducting spheres A and B, each carrying a charge of +Q. They are placed in a vacuum with their centres separated by a distance d, where d is of the same order of magnitude as the radii of the two spheres.

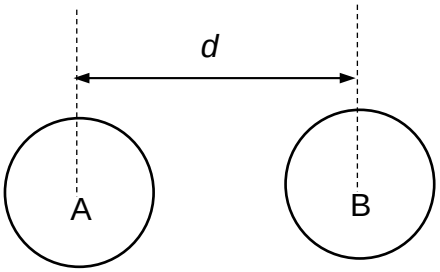

Fig. 6.1

Explain why the electric force, F between the two spheres is not given by the expression:

$$F = \frac{Q^2}{4\pi\varepsilon_o d^2}$$

……

……

……

…… [2]

(c) An isolated conducting sphere R has a radius of 40.0 cm, and the charge on the sphere is +6.67 nC.

(i) Show that the potential on the surface of sphere R is 150 V.

[2]

For Examiner's Use

(ii) A second conducting sphere S which is electrically neutral is now brought close to R. S has a radius 20.0 cm.

A wire is used to connect the surface of sphere S to that of sphere R. After connecting, the charges will redistribute themselves between the surfaces of the two spheres until the potential on the surfaces of both spheres are the same.

Show that $\frac{\text{final charge on S}}{\text{final charge on R}} = \frac{1}{2}$.

[2]

(iii) Hence, determine the final electric potential on the surface of the two spheres.

potential = …… V [3]

(d) Fig. 6.2 shows two parallel metal plates P and Q situated 8.0 cm apart in air.

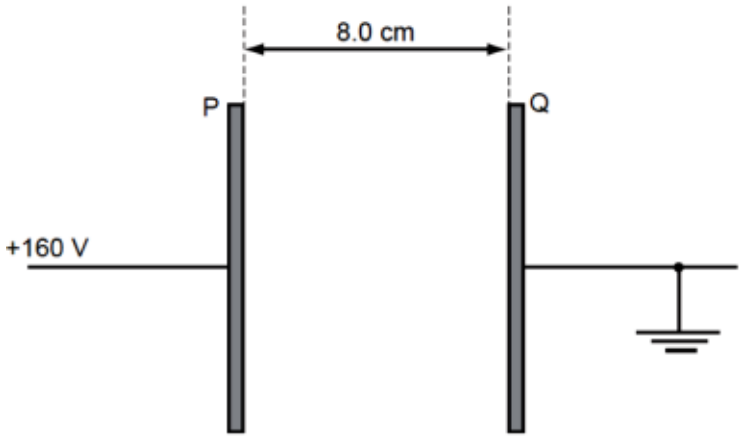

Fig. 6.2

For Examiner's Use

Plate Q is earthed while plate P is maintained at a potential of +160 V.

(i) On Fig.6.2, draw lines to represent the electric field in the region between the plates.

[2]

(ii) Show that the magnitude of the electric field strength between the plates is 2000 V m^{-1}.

[1]

(iii) A dust particle is suspended in the air between the plates. The particle has charges of $+1.2\times10^{-15}$ C and -1.2×10^{-15} C near its ends.

The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 6.3.

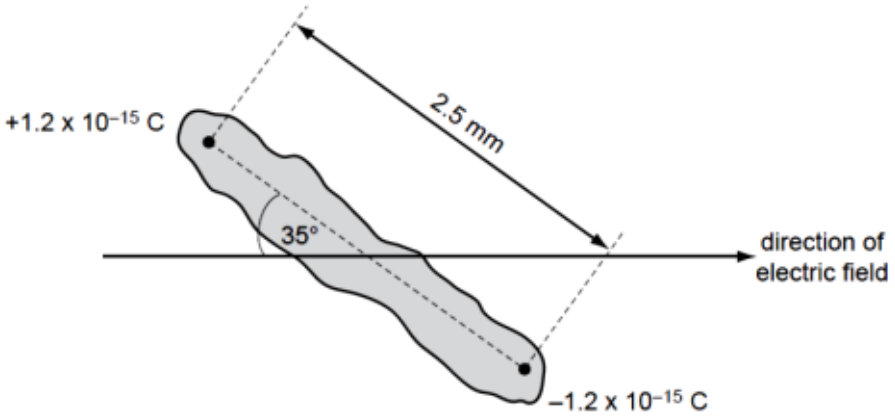

Fig. 6.3

The particle makes an angle of 35° with the direction of the electric field.

1. Draw on Fig.6.3, arrows to show the direction of the electric force on each charge due to the electric field.

[1]

2. Calculate the magnitude of the electric force on each charge due to the electric field.

force = …… N [2]

3. Determine the magnitude of the couple acting on the particle at this instant.

couple = …… N m [2]

For Examiner's Use

4. Suggest the subsequent motion of the particle in the electric field.

……..

……..

……..

…… [2]

For Examiner's Use

7 **(a)** State what is meant by

(i) *nuclear binding energy*,

……

..... [1]

(ii) *nuclear fusion*.

……

..... [1]

(b) A possible reaction for use in a nuclear fusion reactor is one in which the deuterium and tritium nuclei fuse together to produce a helium nucleus.

Fig. 7.1 below shows the nuclear binding energies (BE) per nucleon for some particles.

particle	BE per nucleon / MeV
neutron, ${}^{1}_{0}n$	0
deuterium, ${}^{2}_{1}H$	1.11
tritium, ${}^{3}_{1}H$	2.83
helium, ${}^{4}_{2}He$	7.07

Fig. 7.1

(i) Complete the following nuclear equation to represent the fusion of the deuterium and tritium nuclei.

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow ..... + ... + \text{energy released}$$

[1]

(ii) Using values from Fig. 7.1, determine the energy released in the process in **b(i).**

energy released = …….. MeV [2]

(iii) Fig. 7.2 below shows the masses for the neutron and various nuclei.

particle	mass / u
neutron, $^{1}_{0}n$	1.00867
deuterium, $^{2}_{1}H$	2.01356
tritium, $^{3}_{1}H$	3.01551
helium, $^{4}_{2}He$	4.00151

Fig. 7.2

By considering the change in mass during the nuclear fusion reaction, determine the energy released in the process in **(b)(i)**.

energy released = …….. MeV [2]

(iv) Suggest why for nuclear fusion reactions to take place, high temperatures are required.

…….....

…….....

…….....

…….....

..... [3]

(v) In the doughnut-shaped Tokamak Fusion Test Reactor, the deuterium-tritium fuel can reach temperatures of up to 5.1×10^{8} K , more than thirty times the core temperature of the sun.

No material can withstand the extreme temperature of the deuterium-tritium fuel.

Suggest one way of confining the deuterium-tritium fuel in the fusion reactor, without the walls of the reactor coming into contact with it.

…….....

…….....

……..... [2]

For Examiner's Use

(vi) Suggest one advantage of nuclear fusion over nuclear fission as a means of energy production.

…….....

……..... [1]

(c) The mass of a sample of Tritium is 1.0 g. The nuclide Tritium has a *half life* of 12.3 years.

(i) Define *half life* of a radioactive substance.

…….....

..... [1]

(ii) Find the number of Tritium atoms in the sample.

number of Tritium atoms = …… atoms [1]

(iii) Determine the decay constant for Tritium.

decay constant = …… s^{-1} [2]

(iv) Calculate the fraction of Tritium atoms which remained after 20 years.

fraction = …….. [3]

For Examiner's Use

8 **(a)** Define the *tesla*.

……

……

…… [3]

(b) An electron is travelling with momentum p in a vacuum. It enters a region of uniform magnetic field of flux density 0.24 T, as shown in Fig. 8.1.

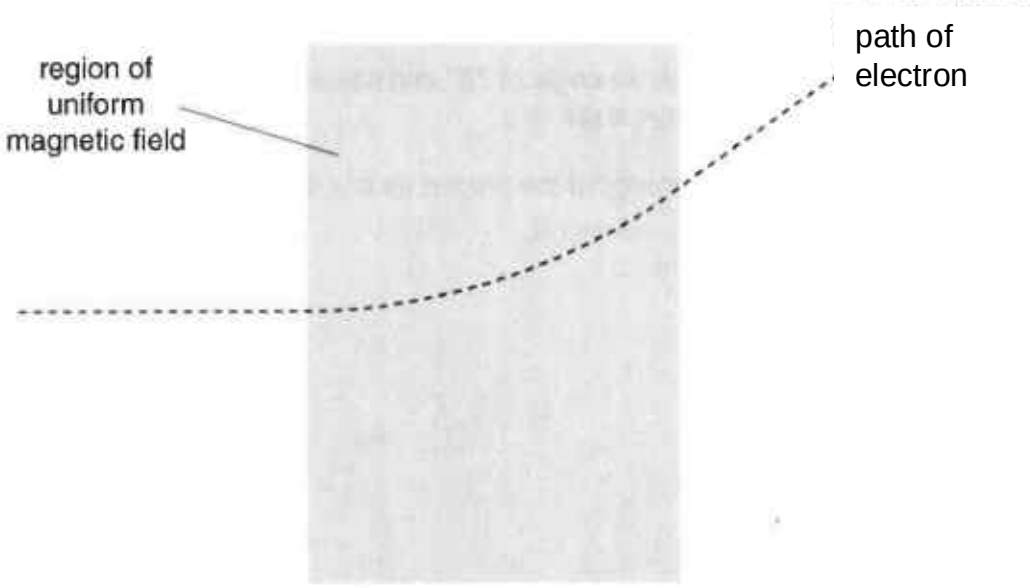

Fig. 8.1.

When the electron is in the magnetic field, it is travelling at right-angles to the direction of the field.

(i) Explain why the path of the electron in the magnetic field is an arc of a circle.

……

……

……

……

……

…… [3]

(ii) Draw in Fig. 8.1. the direction of the magnetic field. [1]

For Examiner's Use

(iii) The radius of the circular path of the electron in the magnetic field is 6.2 cm.

Calculate the momentum p of the electron.

p = …….. N s [3]

(c) Electrons are produced in beta decay. One example would be the beta decay of the Bismuth-210 nucleus to produce an electron and a Polonium-210 nucleus.

Fig. 8.2 below shows the tracks formed by the electron and the Polonium-210 nucleus, following the decay of an initially stationary Bismuth-210 nucleus, in a cloud chamber.

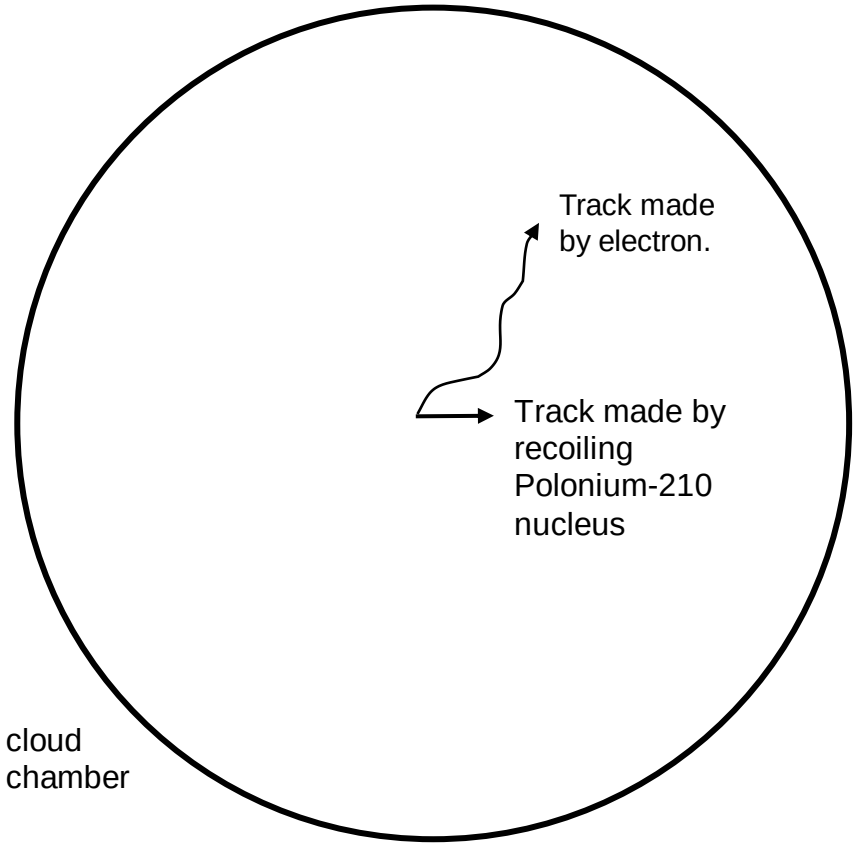

Fig. 8.2

For Examiner's Use

(i) With reference to the directions of the cloud chamber tracks, and the principle of conservation of momentum, explain how a third particle (now known as the anti-neutrino) must have been formed despite not being seen in the cloud chamber.

……...……..

……...……..

……...……..

……...……..

……...…….. [3]

(ii) Draw in Fig. 8.2. an arrow showing the path of the anti-neutrino. [1]

(d) An X-ray photon of wavelength 965.0×10^{-12} m collides elastically with a stationary electron, as illustrated in Fig. 8.3.

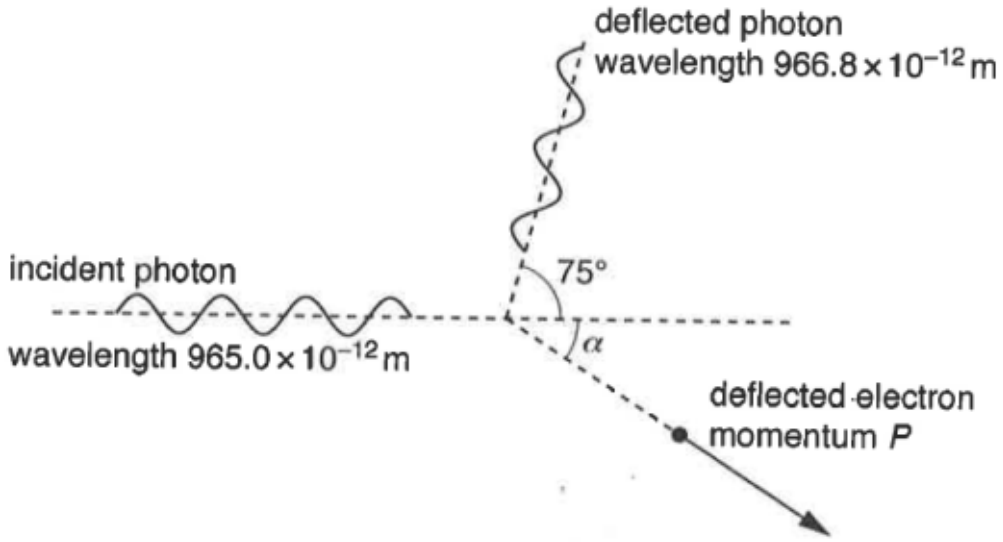

Fig. 8.3.

The photon is deflected through an angle of 75° and has a wavelength of 965.0×10^{-12} m . The electron is deflected through an angle α and has a momentum of 8.36×10^{-25} N s.

(i) Calculate the kinetic energy of the deflected electron.

kinetic energy = …….. J [2]

For Examiner's Use

(ii) By considering the conservation of momentum or otherwise, calculate the angle of deflection, α of the electron in Fig. 8.3.

Explain your working.

angle α = …….. ^{0} [4]

Innova JC
2016 Prelim H2 Physics Paper 1 Solutions

Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	~~A~~	11	C	21	D	31	A
2	B	12	A	22	A	32	D
3	B	13	C	23	C	33	C
4	A	14	B	24	C	34	B
5	D	15	D	25	A	35	D
6	B	16	A	26	A	36	C
7	C	17	C	27	C	37	A
8	D	18	D	28	D	38	D
9	D	19	B	29	C	39	B
10	C	20	A	30	D	40	D

10 A
7 B
11 C
12 D

1 **Solution: A**

Original question does not test on errors, hence modified.

$$s = ut + \frac{1}{2}at^2$$

Since $u = 0$, taking downwards to be positive

$$h = \frac{1}{2}gt^2$$

$$g = \frac{2h}{t^2}$$

$$\frac{\Delta g}{g} = \frac{\Delta h}{h} + 2\frac{\Delta t}{t}$$

$$= \frac{0.002}{0.785} + 2\left(\frac{0.0008}{0.4000}\right)$$

$$= 6.55 \times 10^{-3}$$

t affects the fractional uncertainty of g most.
Although the fractional unceratinty of t is smaller than that of h,
the time is squared in the calculation of g,
hence its contribution to the fractional uncertainty of g is doubled.

2 **Solution: B**

Expressway has a speed limit of 90 km/hr. A typical car has a mass of 1000 kg.
Car's change in momentum = final momentum – initial momentum
= 0 – mv
=0 – (1000)(90x1000/3600)=-25000 kg m s^{-2} (B)

3	**Solution: B** **Modified** $v^2 = u^2 + 2as$ $0 = u^2 + 2as$ $u = \sqrt{-2as}$ for max safe speed, $u_{max} = \sqrt{-2a_{max}s}$ $= \sqrt{-2(-0.215)(1000)}$ $= 20.7 \text{ m s}^{-1}$ I.e. the speed of the train at the yellow signal has to be below 20.7 m s^{-1} otherwise the train either has to: (1) Undergo a larger deceleration than it can withstand, in order to stop within 1 km or (2) Still decelerate at 0.22 m s^{-2} but take more than 1 km to stop. Hence of the four options, B gives the maximum speed that train can pass by the yellow signal, and still stop within 1.0 km, while keeping the deceleration with 0.22 m s^{-2}.
4	**Solution: A** The area under a velocity-time graph over a certain time interval represents the change in displacement during the time interval. For the first half of the journey, the displacement is increasing with respect to time and for the second half of the journey, there is a negative change in displacement (i.e. the object moved backwards towards the reference point), so the graph shows a decreasing displacement.
5	**Solution: D** The force of P on Q and the force of Q on P are an action-reaction pair. Hence the two forces are equal in magnitude but opposite in direction. Alternatively, Total momentum before = Total momentum after $P_{initial,P} + P_{initial,Q} = P_{after,P} + P_{after,Q}$ $P_{after,Q} - P_{initial,Q} = -(P_{after,P} - P_{initial,P})$ $\Delta P_Q = -\Delta P_P$ Area under F-t graph for Q = −Area under F-t graph for P
6	**Solution: B** Newton's 2nd law defines the net force acting on an object as being directly proportional to the rate of change of momentum of the object, where the constant of proportionality is 1. Hence, from this definition, options A and C (rate of change of energy), and option D (Rate of change of force) can be eliminated.

	$F_{\text{exerted by wall on water jet}} = \frac{\Delta p_{\text{water}}}{\Delta t}$ = change in momentum of the water jet per unit time. $F_{\text{exerted by water jet on wall}} = -F_{\text{exerted by wall on water jet}}$ The magnitude of the force exerted by the water jet on the wall is equal to the force exerted by the wall on the water jet. Thus the magnitude of the force exerted by the water jet on the wall is numerically equal to the change in momentum of the water jet per unit time.
7	**Solution: C** Upthrust is a net upward force due to the fluids. It arises from the fluid pressure differences. U = p_b (A) - p_t (A) = (p_b - p_t) (A)
8	**Solution: D** For a car travelling at constant speed, the net force acting on the car is zero. Consider the forces acting parallel to the slope, Sum of forces upward and parallel to slope = sum of forces downward and parallel to slope engine force = component of weight parallel to slope + resistive force engine force = $mg \sin\theta + F$
9	**Solution: D** Taking pivot at where W is acting, as L is moved outwards, the clockwise moment due to L is increased. To maintain rotational equilibrium, the anti-clockwise moment due to R has to increase. Hence, the perpendicular distance has to increase and R moves to the right.
10	**Solution: C** The work done against friction is converted to thermal energy. WD against friction = 60 x 10 = 600 J According to the work-energy theorem, the net work done on the crate = the change in KE of the crate. Net work done = F_{net} x S = (80-60)x 10 = 200 J
11	**Solution: C** P = F_{engine} v Since car is travelling at constant speed, P = $F_{resistive}$ v $F_{resistive} \propto v^2$ $F_{resistive} = kv^2$ $(800) = k (20)^2$ k = 2

	$(F_{resistive}) = (2)(40)^2$ $F_{resistive} = 3200$ N $P = F_{resistive}\ v$ $P = (3200)(40)$ $P = 1.28 \times 10^5$ W
12	**Solution: A** Modified. KE at top of circle $= KE$ at bottom of circle $-$ gain in GPE $= \frac{1}{2}(1.27)\left(5.75^2\right) - (1.27)(9.81)(1.2)$ $= 6.044$ J Linear speed at top of circle: $\frac{1}{2}mv^2 = 6.044$ $v = 3.085$ m s^{-1} Tension at top, $T = F_C - mg$ $= \frac{(1.27)(3.085^2)}{0.6} - (1.27)(9.81)$ $= 7.689$ ≈ 7.69 N
13	**Solution: C** **Some options changed.** Statement A is wrong as a geostationary satellite can only remain vertically above a point above the Earth's equator. for constant ω, v is different for different r. Statement B is wrong since the period of the satellite is fixed at 24 hours, its orbital height is also fixed. Kepler's third law states that $T^2 = \frac{4\pi^2}{GM}R^3$ Statement D is wrong as the linear speed is not equal to that of the Earth. From $v = r\omega$,
14	**Solution: B** At r distance away, GPE, $-\frac{GMm}{r}$ = – 3.2 MJ At $2r$ distance away, for the second satellite, GPE, $-\frac{GMm}{2r}$ = – (1/2) x 3.2 MJ

	= – 1.6 MJ Since KE = ½ |GPE| = ½ (1.6 MJ) = 0.8 MJ Total energy of the second satellite, E = KE + EPE = 0.8 MJ + (– 1.6 MJ) = – 0.8 MJ
15	**Solution: D** Speed, $v = \omega \sqrt{(x_o^2 - x^2)}$, At x = 0 $v = \omega (x_o)$ $= 2\pi (319) (0.50 \text{ mm})$ $= 1002 \text{ mm s}^{-1}$ $=1000 \text{ mm s}^{-1}$ (3 sf)
16	**Solution: A** Fact. A larger damping effect will cause all the amplitudes to be reduced at all frequencies.
17	**Solution: C** mL = Pt (1): $L = Pt_1 / m$ $mc\Delta\theta = Pt$ (2): $c = Pt_2 / m\Delta\theta$ $\frac{(1)}{(2)} : \frac{L}{c} = \frac{Pt_1}{m} \div \frac{Pt_2}{m\Delta\theta}$ $= t_1 \times \frac{\Delta\theta}{t_2} = 40 \times 4.0 = 160K$
18	**Solution: D** p = 1/3 (density) $<c^2>$ $\sqrt{<c^2>} = \sqrt{\frac{3p}{(density)}}$ $= \sqrt{\frac{3(1.00 \times 10^5)}{(1.6)}} = 433 \text{ m s}^{-1}$
19	**Solution: B** $\frac{\Delta\theta}{2\pi} = \frac{\Delta x}{\lambda} \quad \Rightarrow \quad \frac{\pi/3}{2\pi} = \frac{0.40}{\lambda}$ Since phase difference of $\frac{\pi}{3}$ = 0.40 m, the wavelength = 0.40 x 6 = 2.40 m Thus, speed = $f\lambda$ = 200 x 2.40 = 480 ms^{-1}
20	**Solution: A** The sound generated by the vibrating string is a *progressive* longitudinal wave.

21	**Solution: D** At the 1st order bright fringe, the waves meet at in phase with the phase difference of 2π. From the graph, $Distance\ x\ of\ 1st\ order\ bright\ fringe\ from\ C = 2.4\ mm$ (phase diff 2π) $Distance\ CP, \Delta x = 4.2\ mm$ (phase diff $\Delta\theta$) Using ratio, $\frac{\Delta\theta}{2\pi} = \frac{\Delta x}{x}$ $Phase\ angle\ at\ Q\ = \frac{4.2}{2.4} \times 2\pi = \frac{7}{2}\pi$ Equivalent phase difference $= \left(\frac{7}{2}\pi - 2\pi\right) = \frac{3}{2}\pi\ (principle\ value)$
22	**Solution: A** Use formula for diffraction grating: $d \sin\theta = n\lambda$ $d = 10^{-3}$ m / 625 = 1.60 × 10^{-6} m n = 1 $\theta = 20°$ (1.60 × 10^{-6}) sin20° = (1)(λ) λ = 5.47 x 10^{-7} m = 550 nm (2 s.f.)
23	**Solution: C** A: see explanation for C B: see explanation for C C: negative ion is initially projected into the in the same direction as the electric field. After some time, the negative ion will de-celerate and changes the magnitude and direction of the velocity. D: negative ions accelerate in the opposite direction to the electric field.
24	**Solution: C** Electric field strength, $E = \frac{\Delta V}{\Delta d} = \frac{12}{1.0 \times 10^{-3}} = 12000$ NC^{-1} Work done, W = q ΔV = (3.9 x 10^{-6}) (12) = 4.7 x 10^{-5} J
25	**Solution: A** Question changed, unclear. At 0.10 A, the p.d. across the resistor is 1 V, and the p.d. across the thermistor is 2 V. The today p.d. is thus 3 V which is equal to the emf of the cell. ~~Same current through both components. Hence use graph to find a value of current where the 2 pd add up to 3.0 V → 0.1 A~~ ~~To maintain same current with doubled resistance of resistor, pd across resistor is 2.0~~

	~~V. Hence new e.m.f is 2.0 + 2.0 = 4.0 V~~
26	**Solution: A** Q = It = 0.50(1000) = 500 C E = W/Q = 4500/500 = 9.0 V
27	**Solution: C** Modify question so that students will not make use of Emf calculated in previous question otherwise double penalise if wrong. Energy dissipated in variable resistor = P x t $=I^2Rt$ $=(0.50)^2(16)(1000)$ =4000 J Thus energy dissipated due to internal resistor will be 500 J. ~~I = E/(R+r) = 9.0/(16+r) = 0.50~~ ~~r = 2.0 Ω~~
28	**Solution: D** Originally: $R_{total} = \left(\frac{1}{2R} + \frac{1}{2R}\right)^{-1} = R$ $I_{total} = \frac{E}{R}$ $I_P = I_Q = I_R = I_S = \frac{E}{2R}$ $P_P = P_Q = P_R = P_S = \left(\frac{E}{2R}\right)^2 R = \frac{E^2}{4R}$ Final: $R_{total} = \left(\frac{1}{R} + \frac{1}{R}\right)^{-1} + R = \frac{3R}{2}$ $I_{total} = \frac{2E}{3R}$ $P_R = \left(\frac{2E}{3R}\right)^2 R = \frac{4E^2}{9R}$ $P_Q = P_S = \left(\frac{E}{3R}\right)^2 R = \frac{E^2}{9R}$ Hence P brighter, Q and S dimmer
29	**Solution: C** At A, both the magnetic fields of X and Y are directed upwards. Hence the field would be non-zero. At D, both the magnetic fields of X and Y are directed downwards. Hence the field would also be non-zero.

	At B, both the magnetic fields of X and Y are directed opposite to each other but do not cancel out each other as the field due to X (which is closer) will be stronger than the field due to Y. Hence the field would also be non-zero At option C, both the magnetic fields due to X and Y are equal in magnitude but opposite in direction. Thus the net field will be 0.
30	**Solution: D** When magnet is at the **starting position**, the **speed is close to zero**, the **magnetic field is also weak**, hence the **change in flux linkage and thus the induced emf is close to 0**. (Eliminate Option C). When the **magnet passes through centre of the coil**, the **speed is large**, but the **change in magnetic flux linkage is small (as the strength of the magnetic field is about constant**, thus the induced emf is also close to zero. When magnet leaves coil, and is **far from coil**, **speed is large**, but **B-field is very weak** thus the **change in magnetic flux linkage is very small**, the induced emf is close to 0. (Eliminate Option A) We expect the **induced emf to be of opposite polarity** when the **magnet enters and leaves the coil** thus we can eliminate **option B and the answer is option D**.
31	**Solution: A** Induced emf, $E_{\text{induced}} = Blv$ $= (0.12)(0.093)(0.23)$ $= 2.57 \times 10^{-3}$ V Alternatively: $E_{\text{induced}} = -\dfrac{\Delta\Phi}{\Delta t}$ $= -\dfrac{\Phi_{\text{final}} - \Phi_{\text{initial}}}{\Delta t}$ $= -\dfrac{0 - (0.12)(0.093)(0.23)}{1.0}$ $= 2.57 \times 10^{-3}$ V Induced currrent $I = \dfrac{E_{\text{induced}}}{R}$ $= \dfrac{2.57 \times 10^{-3}}{1.0}$ $= 2.57 \times 10^{-3}$ A The flux linkage through the circuit is decreasing. Hence current will flow in the clockwise direction, generating an induced B-field into the page, to oppose the decrease in flux linkage.
32	**Solution: D**

	By potential divider concept, pd across increased resistance will increase, hence pd across XY will decrease. In order to maintain zero deflection, total pd tapped should remain unchanged. Hence longer length needed (towards Y)
33	**Solution: C** <P> = ½ V_o^2/R = ½ × 42 /10 = 0.80 W
34	**Solution: B** Power for 3 lamps = 3 × 24 = 72 W Input current = 72 W / 240 V = 0.30 A
35	**Solution: D** $(E_3 - E_1) = (E_3 - E_2) + (E_2 - E_1)$ $\frac{hc}{\lambda_1} = \frac{hc}{\lambda_2} + \frac{hc}{\lambda_3}$ $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2}$ $\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_2 - \lambda_1}$
36	**Solution: c** **Changed original question on Heisenberg uncertainty.** Lines at the high energy end i.e. high frequency or low wavelength, are closer together as the difference in energy is smaller. Lines at the low energy end i.e. low frequency or large wavelength are further apart due to the larger difference in energy.
37	**Solution: A** The fast decay transitions in scheme A facilitates population inversion best because it causes the upper lasing level to be populated and the lower lasing level to be emptied quickly. The ground state can never be totally emptied hence option B and C is non-ideal. Option C and option D have only two energy levels, 2-states lasers are not possible. In fact for option D, population inversion is not possible.
38	**Answer: D** Donor → more electrons as charge carriers, thus X is n-type Acceptor → more holes as charge carriers, thus Y is p-type In this connection, the n-type semiconductor is connected to positive terminal while the p-type semiconductor is connected to the negative terminal. The external E field will reinforce the internal one, thus no current will flow as depletion region expands → **reverse bias**
39	**Solution: B**

	On the reason for 1, the α - particles **do not miss** the gold atoms but rather the **atoms are made up of mostly empty space**, hence most of the α - particles would **miss the nuclei instead**. Occasionally, an α **- particle comes sufficiently close to the nucleus**, and is **deflected by the positively-charged nucleus**. Hence, it is **not very accurate** to say the α **- particles bounce off the gold atoms or the gold surface**.
40	**Solution: D** $Rn\ {}^{222}_{86} \rightarrow Pb\ {}^{206}_{82} + 4\ He\ {}^{4}_{2} + 4\ e\ {}^{0}_{-1}$ Since four beta particles produced, four of the intermediate daughter nuclides must have been beta-emitters.

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9646/02

Paper 2 Structured Questions **19 August 2016**

1 hour 45 minutes

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 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.

Answer **all** questions.

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.

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1	/11
2	/7
3	/9
4	/11
5	/7
6	/15
7	/12
Significant Figures	
Total	/72

This document consists of **20** printed pages.

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}
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	$= p\Delta V$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
hydrostatic pressure,	p	$= \rho gh$
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	$= v_o \cos \omega t$
		$= \pm\omega\sqrt{\left(x_o^2 - x^2\right)}$
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	$= x_o \sin\omega t$
transmission coefficient	T	$= \exp(-2kd)$
	where k	$= \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{½}}$

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1 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. 1.1.

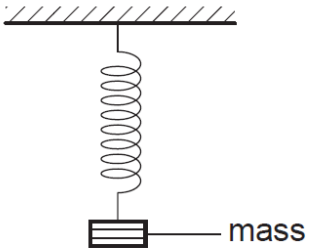

Fig. 1.1

(a) The mass is in translational equilibrium. Explain, with reference to the forces acting on the mass, what is meant by translational equilibrium.

There is no net resultant force in all directions. [B1]
The weight downwards is equal to the tension upwards. [B1]

.....
.....

..... [2]

(b) The mass is pulled down and then released at time $t = 0$. The mass oscillates up and down. The variation with t of the displacement of the mass d is shown in

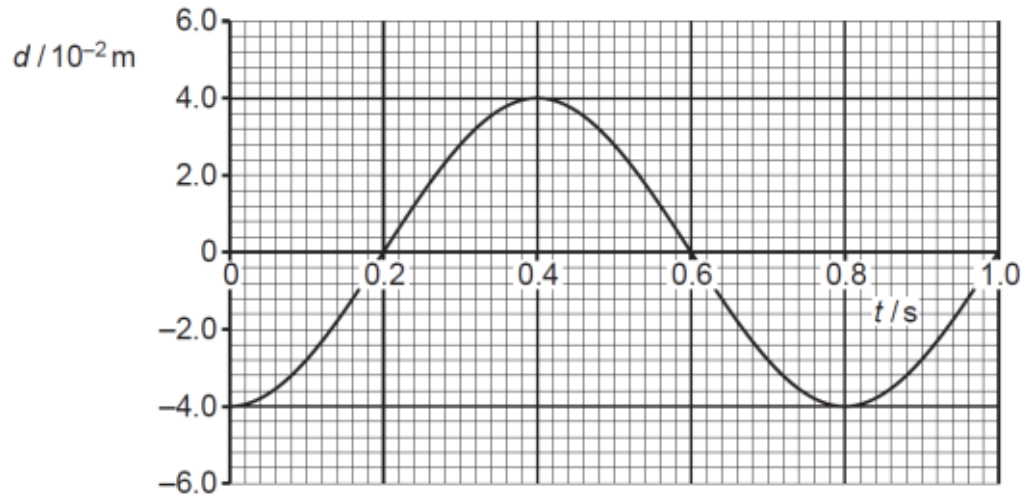

Fig. 1.2.

Fig. 1.2

Using Fig. 1.2, state an instant when

(i) the elastic potential energy stored in the spring is a maximum,

0, 0.8 s (any one of these values) [A1]

time = ... s [1]

(ii) the mass is in equilibrium.

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0.2, 0.6, 1.0 s (any one of these values) [A1]

time = ... s [1]

(c) The arrangement shown in Fig. 1.3 is used to determine the length l of a spring when different masses M are attached to it.

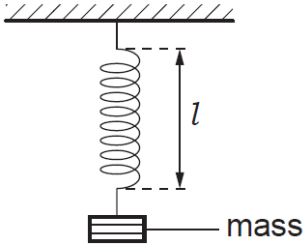

Fig. 1.3

The variation with mass M of l is shown in Fig. 1.4 below.

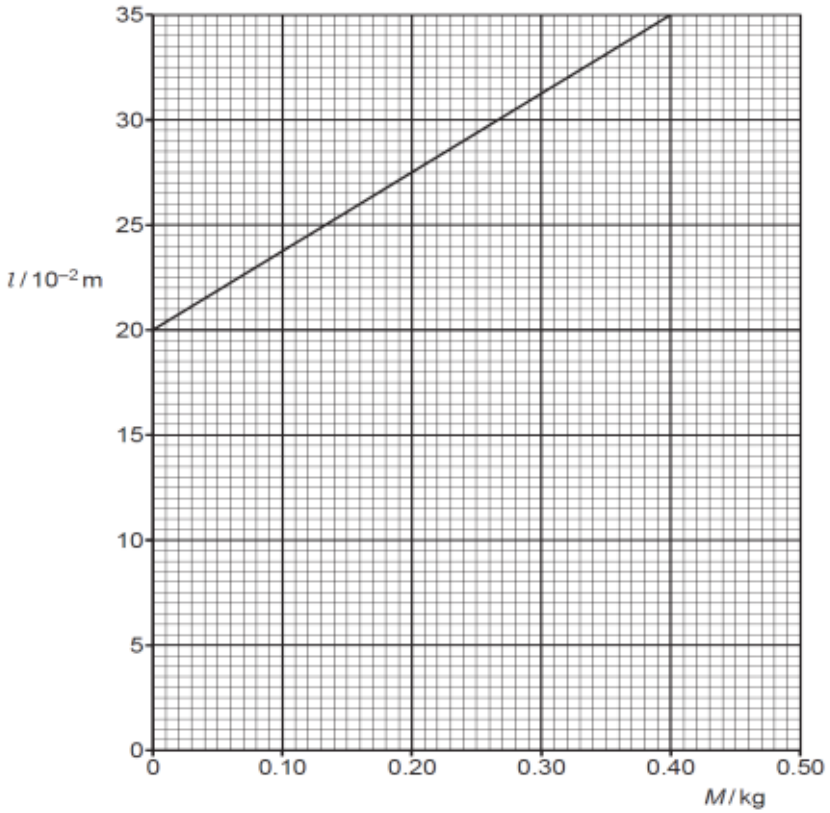

Fig. 1.4

(i) State and explain whether the spring obeys Hooke's law.

The spring obeys Hooke's Law. [B1]
From the linear/straight line graph, it suggests that the mass is proportional to the extension, hence the applied force (W=mg) is proportional to extension. [B1]

[2]

(ii) Show that the spring constant of the spring is 26 N m^{-1}. [2]

Solution

Use of the gradient of *F-x* graph (not $F = kx$) [C1]

$$k = \frac{(0.40 \times 9.81) - 0}{(35 - 20) \times 10^{-2}}$$ [M1]

k = 26 N m^{-1} [A0]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

Solution

energy = area under the F-x graph or energy = ½ *F x* [M1]

= ½ (0.40 × 9.81) (15 × 10^{-2}) [M1]

= 0.294 J [A1]

energy = …… J [3]

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2 **(a)** State the first law of thermodynamics.

The increase in the internal energy of the system is the sum of the heat supplied to and work done on the system. [B1]
"Change in internal energy" is too vague and not accepted.

……[1]

(b) During the first part of the power stroke in a diesel engine, the pressure of the burning gas remains constant at 8.00×10^6 Pa, while the volume of the gas increases from 3.00×10^{-5} m^3 to 7.10×10^{-5} m^3.

(i) Calculate the work done on the gas during the first part of the power stroke.

Solution
Work done on the gas = $-p\,\Delta V$
$= -(8.00 \times 10^6)(7.10 \times 10^{-5} - 3.00 \times 10^{-5})$ [M1]
$= -328$ J [A1]

If student indicate +328 J, or use $W = p\Delta V$ i.e. no negative sign,
1 mark will be awarded.

work done on gas = …… J [2]

(ii) While this expansion is taking place, the temperature of the gas rises by 900 K. The mass of the gas is 1.27×10^{-3} kg and its specific heat capacity at constant pressure is 1.004×10^3 J kg^{-1} K^{-1}. The gas is diatomic.

Calculate the heat gained by the burning gas.

Solution
Heat gained, $Q = m\,c\,\Delta\theta$
$= (1.27 \times 10^{-3})(1.004 \times 10^3)(900)$
$= +1150$ J [A1]

Note: values for specific heat capacity only exists for the isovolumetric and isobaric processes, none of adiabatic.

heat gained = …… J [1]

(iii) Hence find the increase in internal energy during the first part of the power stroke in the diesel engine.

Solution
$\Delta U = Q + W = (+1150) + (-328) = +822$ J

increase in internal energy = …… J [1]

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(iv) The gas subsequently undergoes the following processes:

1. second part of the power stroke being an adiabatic expansion from 7.10×10^{-5} m^3 to 9.00×10^{-5} m^3.

2. third part of the power stroke being an isothermal compression from 9.00×10^{-5} m^3 back to its original starting state at 3.00×10^{-5} m^3.

Sketch and label, in Fig. 2.1 below, all three parts of the power stroke in the diesel engine. The starting point of the power stroke, point A, has been drawn for you.

[2]

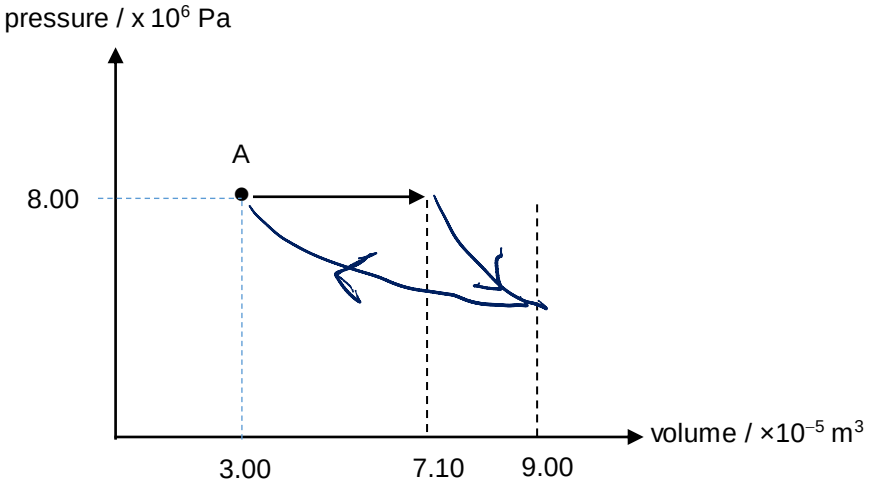

Fig. 2.1

Solution
The diagram consists of 3 arrows;
1. horizontal arrow direction to the right from A to B.
2. steep slope downwards from B to C.(adiabatic process)
3. less steep slope upwards from C to A. (isothermal process)

1 mark for correct values of 7.10×10^{-5} & 9.00×10^{-5} m^3.
1 marks for correct 3 arrows with directions.

3 **(a)** **(i)** Define the electromotive force of a cell.

The electromotive force of a cell is defined as the energy converted from other forms to electrical energy per unit charge passing through the source. [B1]

[1]

(ii) Explain why the terminal potential difference of a cell is usually smaller than its electromotive force.

When current flows through the battery, there is a potential drop due to the internal resistance of the cell. Hence terminal p.d. is always smaller than e.m.f. [B1]

[1]

(b) Fig. 3.1 shows a circuit containing a cell and four resistors.

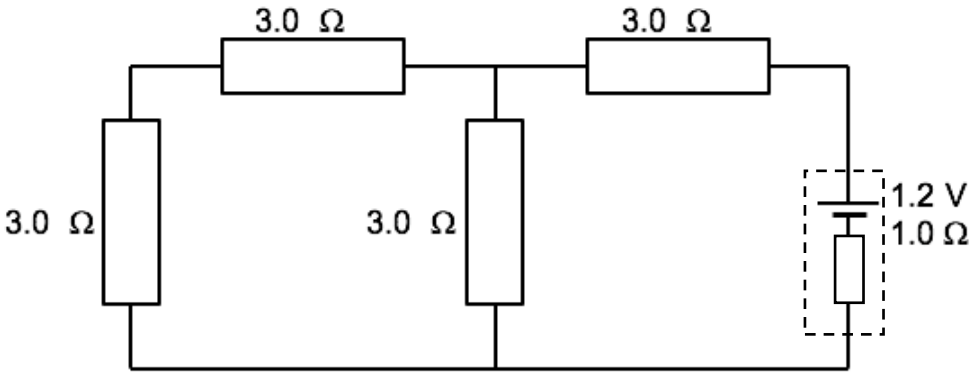

Fig. 3.1

Calculate

(i) the current through the 1.2 V cell,

Solution

$R_T = \left(\frac{1}{6.0} + \frac{1}{3.0}\right)^{-1} + 3.0 + 1.0$ M0

$R_T = 6.0\ \Omega$ M1

$I = \frac{E}{R_T} = \frac{1.2}{6.0} = 0.2\ \text{A}$ A1

current = ... A [2]

(ii) the terminal p.d. of the 1.2 V cell,

$V = E - Ir$

$V = 1.2 - 0.2(1.0)$ M0

$V = 1.0\ \text{V}$ A1

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terminal p.d. = …….. V [1]

(iii) the efficiency of the circuit.

$$\frac{P_V}{P_E} = \frac{IV}{IE}$$

$$\frac{P_V}{P_E} = \frac{1.0}{1.2} \qquad \text{M0}$$

$$\frac{P_V}{P_E} = 83\% \qquad \text{A1}$$

efficiency = …… % [1]

(c) Fig. 3.2 below shows 2 coils X and Y wound on a soft iron core.

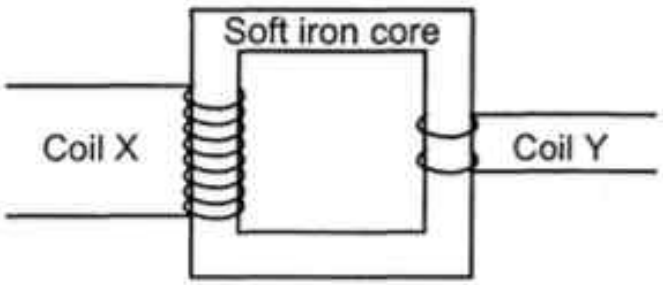

Fig. 3.2

The inputs of coil X is now connected to a 240 V mains supply, where the current changes directions 100 times per second. The output of coil Y is connected to a 12 V, 3.0 A light bulb, the bulb is working normally.

(i) Assuming that the efficiency of the transformer is 90%, make use of energy considerations to calculate the current in coil X.

$$P_{out} = VI = 12(3) = 36 \text{ W} \qquad \text{M0}$$

$$P_{in} = \frac{P_{out}}{0.90} = 40 \text{ W} \qquad \text{M1}$$

$$I_{in} = \frac{P_{in}}{V_{in}} = \frac{40}{240} = 0.167 \text{ A} \qquad \text{A1}$$

current = …… A [2]

(ii) Suggest one reason why the transformer is not 100% efficient.

Loss of energy through generation of eddy currents in the soft iron core.
Loss of energy through hysteresis effect
Loss of energy through heat generated by current flowing through the solenoids and wires.
Any one: B1

..... [1]

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4 **(a)** State the laws of electromagnetic induction.

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**. [B1]
Lenz's law states that the **induced e.m.f. will be directed** such that the **current** which it causes to flow **opposes the change that is producing it**. [B1]

..... [2]

(b) **(i)** A solenoid is connected in series with a resistor, as shown in Fig. 4.1.

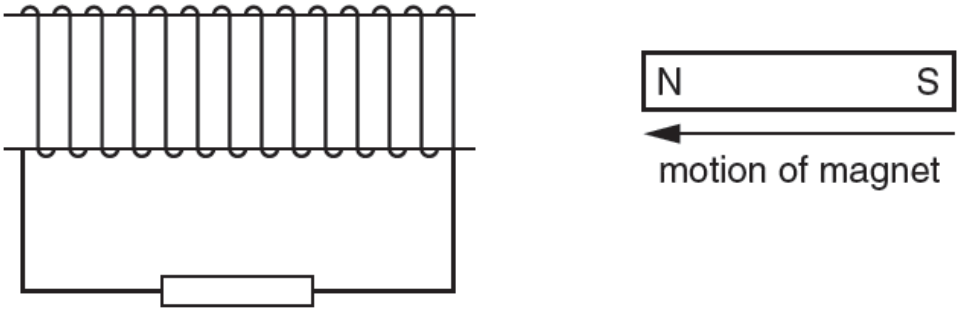

Fig. 4.1

As the magnet is being moved into the solenoid, thermal energy is generated in the resistor.

Use the laws of electromagnetic induction to explain the origin of this thermal energy.

1. As the magnet approaches the solenoid, the **magnetic field strength** in the region in the solenoid **increases**. Hence the **magnetic flux linkage** through the solenoid **increases**. [B1]

2. **By Faraday's law, an e.m.f. is induced** in the solenoid that is directly proportional to the rate of change of magnetic flux linkage. **An induced current thus flows through the circuit** causing the **resistor to heat up**. [B1]

3. By lenz's law, the induced current will flow in the clockwise direction in the circuit so as to produce **an induced north pole facing the approaching magnet**. **Work is done by an external force** to **overcome the repulsive force** and move the magnet towards the solenoid. [B1]

4. Hence, the **mechanical work done by the external force** is converted into **electrical energy** and **eventually thermal energy in the resistor.** [B1]

..... [4]

(ii) Draw in Fig. 4.1. the direction of the induced current in the solenoid. [1]

(c) Explain why the alternating current in the primary coil of a transformer is not in phase with the alternating e.m.f. induced in the secondary coil.

The **alternating current in the primary coil** sets up **a changing magnetic field in the primary coil and hence the soft iron core**. [B1]

Thus the **primary current** is **in phase with the changing magnetic field and magnetic flux in the soft iron core, and also the magnetic flux linkage in the secondary coil.** [B1]

By Faraday's law, the **changing magnetic flux linkage** in the secondary coil **induces an emf** in the secondary coil. [B1]

This induced emf is in phase with the rate of change of magnetic flux linkage in the secondary coil, **and not the magnetic flux linkage per se**. Thus the **induced emf is not in phase with the primary current**. [B1]

[4]

5 **(a)** Explain, using band theory, why the conductivity of an intrinsic semiconductor increases when temperature increases.

When temperature increases, more electrons are able to gain sufficient energy to overcome the narrow forbidden band (or energy gap) to transit into the conduction band. [B1]
Thus, its conductivity increases due to the increase in the number of charge carriers with temperature. More electrons in the conduction band and more holes in the valence band. [B1]

[2]

(b) Explain why the conductivity of a metal decreases when temperature increases.

When temperature increases, the lattice ions vibration will also increase. [B1]
This causes the net flow of the charge carriers across the metal to be impeded due to the frequent collisions the charge carriers make with the lattice ions. Thus, its conductivity is reduced. [B1]

[2]

(c) **(i)** Explain, using band theory, how the introduction of small amounts of Group 5 impurities to intrinsic semiconductors improves their conductivities.

In a n-type semiconductor, the donor atoms introduce an energy level (called **donor level**) that is just slightly below the conduction band.[B1]
As the **energy gap is smaller** now, more electrons are able to move from the donor level to the conduction band. The increased in the number of electrons increase the conductivity of the n-type semiconductor. [B1]

[2]

(ii) However, when too many impurity atoms are introduced, as in the case of highly-doped semiconductors, the resistance of the semiconductor actually increases, rather than decrease, when temperature increases.

With reference to your answer to **(b)**, suggest a reason for this behavior of highly-doped semiconductors.

A highly doped semiconductor will have relatively larger number of charge carriers causing it to **behave more like a conductor (metal).** Thus, when the temperature increases, with increased lattice ions and charge carriers interaction, the electron flow is hampered and so its resistance will increase. [B1]

[1]

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6 A scintillation counter is an instrument that detects and measures high energy charged particles. A scintillation counter comprises three main components i.e.

Component 1: Scintillator material
Component 2: Photocathode
Component 3: Photomultiplier tube

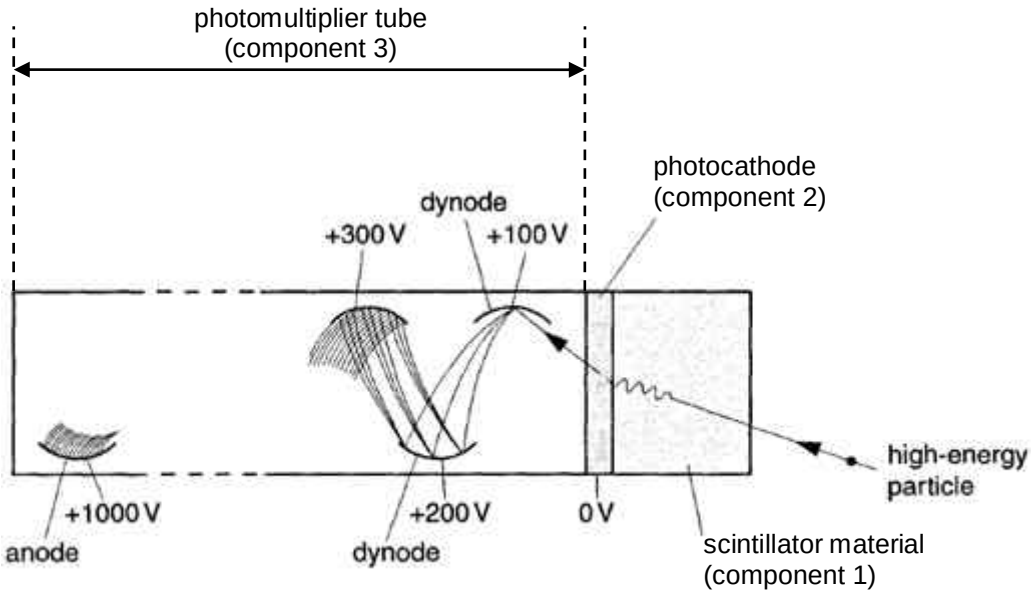

Fig 6.1

(a) In the scintillator material (component 1), high energy particles interact with the material to produce photons.

In one particular experiment, high energy particles produce 90 nW of light of wavelength 400 nm in the scintillator material.

(i) Calculate the energy, E_p, of a single photon of wavelength 400 nm.

Solution
$E_p = hf = h(c/\lambda) = (6.63\text{x}10^{-34})(3\text{x}10^{8}/(400\text{x}10^{-9}))= 4.97\text{x}10^{-19}$ J [A1]

E_p = ... J [1]

(ii) Show that the rate of photons produced in the scintillator, n_p, is 1.81×10^{11} s^{-1} .

[1]

Solution
power of em radiation
$P = N_p E_p / t$
$n_p = P/E_p$
$N_p/t = (90\text{x}10^{-9}) / (4.9725\text{x}10^{-19})$ [M1] $= 1.8099\text{x}\ 10^{-11} = 1.8\ \text{x}\ 10^{-11}\ s^{-1}$

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(b) When the photons produced in the scintillator material (component 1) reaches the photocathode (component 2), the photons eject some of the surface electrons due to the photoelectric effect.

Radiant sensitivity, S, is defined as the photoelectric current generated by the photocathode divided by the incident radiant flux, ϕ of the incoming photons from the scintillator material.

S is expressed in units of amperes per watts (A W^{-1}).

(i) Starting from the definition of radiant sensitivity and/ or examining its units, show that radiant sensitivity, S, is given by:

$$S = \frac{n_e e \lambda}{n_p h c}$$

where n_e is the rate of emission of photoelectrons and n_p is the rate of photons produced in the scintillator material.

Show your working clearly.

[1]

$S = \frac{I_P}{P} = \frac{n_e e}{n_p E_p} = \frac{n_e e}{n_p h \frac{c}{\lambda}}$ where n_p is the rate of photons incident on the photocathode, h is the Planck constant, c is speed of light in vacuum, λ is wavelength of incident radiation (in m)

(ii) Quantum efficiency, η, is defined as the number of photoelectrons emitted, N_e, from the photocathode divided by the number of incident photons, N_p.

$$\eta = \frac{N_e}{N_p}$$

Quantum efficiency can also be calculated from the radiant sensitivity, S, of the photocathode.

Using the expression for S in **b(i)** or otherwise, show that the quantum efficiency, η, can be expressed as:

$$\eta = 1.24 \times 10^{-6} \frac{S}{\lambda}$$

[2]

$$\eta = \frac{N_e}{N_p} = \frac{n_e}{n_p}\frac{t}{t}$$

$$S = \frac{n_e e}{n_p h\frac{c}{\lambda}} = \frac{n_e te}{n_p th\frac{c}{\lambda}}$$

$$\eta = \frac{h\frac{c}{\lambda}}{e}S = \frac{6.63\times10^{-34}(3\times10^{8})}{1.6\times10^{-19}}\frac{S}{\lambda}$$

$$\eta = 1.24\times10^{-6}\frac{S}{\lambda}$$

(c) Fig. 6.2 shows the variation of the radiant sensitivity, S with the wavelength of the incident photons, for various types of photocathodes.

The graph uses a logarithmic scale.

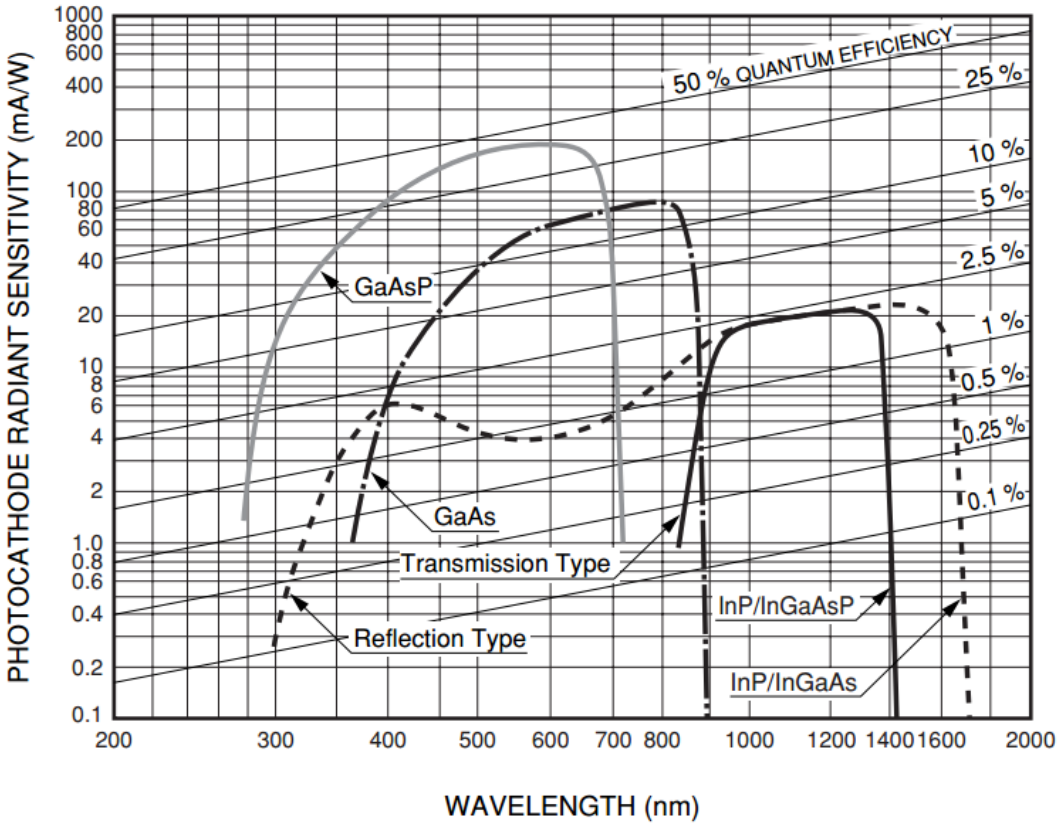


Fig. 6.2

In the experiment detailed in **(a)**, the Gallium Arsenide Phosphide (GaAsP) photocathode was used in the scintillation counter.

(i) Using Fig. 6.2, state and explain which photocathode would not have been suitable for use in the experiment.

InP/InGaAsP (or transmission type)[A1] is not suitable for use in this experiment because it can only detect radiation over a narrow range of between 850 and 1400 nm, which is in the infra-red region. [B1]

……

…… [2]

(ii) Using values from Fig. 6.2, determine the rate of emission of photoelectrons, n_e from the GaAsP photocathode in the experiment detailed in **(a)**.

Solution
From the graph, when λ=400 nm, S=90 mA/W. [A1-graphical interpretation skill]

$$\eta = \frac{1.24\times10^{-6}}{\lambda} S = \frac{1.24\times10^{-6}}{400\times10^{-9}}(90\times10^{-3}) = 0.279$$

$$\eta = \frac{n_e}{n_p} = \frac{n_e}{1.8\times10^{11}} = 0.279$$

$$n_e = 5.02\times10^{10}$$

[M1- correct use of the formula in (b)(ii)]
[A1- correct final answer]

n_e = …… s^{-1} [3]

(d) In the photomultiplier tube (component 3), the photoelectrons emitted from the photocathode are accelerated towards the first positive dynode because of the 100 V potential difference between the dynode and the photocathode.

The kinetic energy of the electron is sufficient to eject, on average, 3 'secondary' electrons from the dynode. These electrons are then accelerated towards the next dynode and the whole process is repeated.

Eventually a tiny pulse of charge is detected at the anode in the photomultiplier tube and measured as the anode current.

(i) The work function energy of the photocathode material is 3.5×10^{-19} J .

Calculate the maximum kinetic energy of the photoelectrons just ejected from the photocathode due to the photoelectric effect.
Solution
$E_P = \phi + E_{k\max}$

$4.97x10^{-19}\text{J} = 3.5\ x\ 10^{-19}\text{J} + E_{k\max}$

$E_{k\max} = 4.97x10^{-19} - 3.5\ x\ 10^{-19}$ [M1] $= 1.47\ x\ 10^{-19}$ J [A1]
Allow ecf

maximum kinetic energy of electron = …… J [2]

(ii) For a photomultiplier with 10 dynodes, show that the number of electrons arriving at the anode for **each** photoelectron emitted from the cathode is 3^9 .

For Examiner's Use

Explain your working.

[1]

Solution
No. of electrons arriving at the node for each photoelectron emitted from cathode:
For 1st dynode: 1 photoelectron arrives = 3^0
For 2nd dynode: 3 photoelectrons arrive = 3^1
For 3rd dynode: 9 photoelectrons arrive = 3^2
....
For 10th dynode: $3^9 = 19683$ photoelectrons arrive

(iii) Determine the current detected by the photomultiplier tube's anode.

Solution
$I = An_e e$

$I = 19683(5.022 \times 10^{10})(1.6 \times 10^{-19})$[M1] [A1]

$I = 1.58 \times 10^{-4}$ A

Allow ecf

current = ... A [2]

7 The efficiency η of a glowing filament may be expressed as

$$\eta = \frac{\text{light energy emitted in the visible range}}{\text{electrical energy input}}$$

As light energy emitted in the visible range can be difficult to measure, the efficiency could instead be determined by measuring the amount of wasted energy produced by the filament in the form of thermal energy. The efficiency is subsequently calculated using

$$\eta = 1 - \frac{\text{thermal energy}}{\text{electrical energy input}}$$

The efficiency is thought to depend on the temperature, *T* of the filament. The relationship between the efficiency and the temperature may be written in the form:

$$\eta = aT^b$$

where *a* and *b* are constants.

You are provided with a filament, a beaker with water that is to be used in the determination of the thermal energy produced by the glowing filament, and an infrared thermometer. You may also use any of the other equipment usually found in a physics laboratory.

Design an experiment to determine the relationship between η and T.

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 η and *T* is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

For Examiner's Use

Q8 Thinking Process

Independent Variable: **Temperature of the filament**, measured using [illegible] thermometer. Temperature of the filament can be varied by varying the electrical power supplied to the filament.

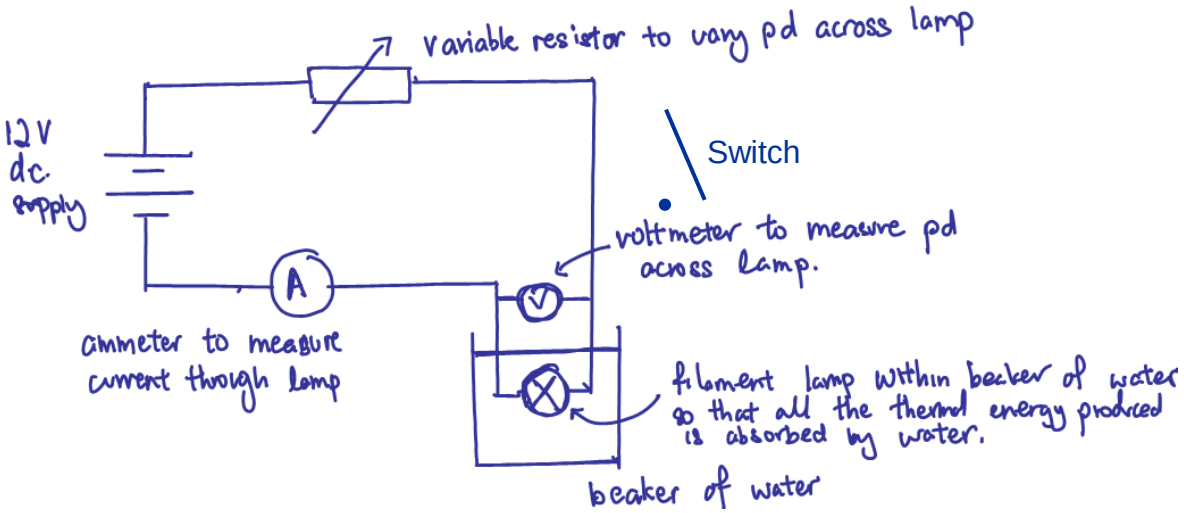
Dependent Variable: **Efficiency**

Requires the **thermal energy** supplied by lamp to water to be measured.
Possible equation to use would be $E = mc\Delta\theta$.
Specific heat capacity of water is known but mass of water and change in temperature needs to be measured.
Mass of water measured using mass balance while change in temperature can be measured using the infrared thermometer.

Electrical energy supplied to lamp also needs to be measured.
Possible equation to use would $E = P.t = I.V.t$
Current and p.d. would require ammeter connected in series, and voltmeter connected in parallel to measure. time can be measured using a stop watch.

Possible Control Variables: **Mass of water, time in heating water**.

Labelled Diagram (Max: 2 marks)
[D1 x 2]



Award one mark only if both are satisfied:

Filament bulb is connected to a **d.c. power supply**.

Circuit should have a **variable resistor**, **an ammeter** connected in series, and **a voltmeter** connected across the lamp.

[Variable resistor can be omitted if student specifies that the voltage input can be varied. If batteries are used than variable resistor is required.]

Award one mark if :

Filament lamp should be **immersed in a beaker of water**.

Control Variables (Max: 2 marks)
[C1x2]

- Keep the **mass of water** used to determine the thermal energy produced by the lamp **constant**.

  This is achieved by **reading the volume of the water in the beaker**, and **ensuring that it remains at the same fixed value before each measurement.**

- Keep the **duration over which the water is heated** a **constant**.

  We can use a **stopwatch** to ensure that the water is **heated for a fixed time** e.g. 5 mins before proceeding to record the readings.

Procedure and Measurement (Max: 3 marks)
[P1x3]

Award 1 mark for:

1. Measure the mass of water using a mass balance. Remember to tare the mass balance before adding water to the empty beaker so that only the mass of the water is recorded.
2. Measure the initial temperature T_i of the water using the infra-red thermometer.
3. Set the variable resistor to a low resistance value, close the switch, and start the stop watch.
4. Record the readings for current, I from the ammeter, readings for the p.d. across the lamp, V are read from the voltmeter, once the values have stabilised.
5. After 5 minutes, open the switch.
6. Remove the bulb from the water, measure and record the highest temperature reached on the infrared thermometer, T_f for the water.
7. Also, measure and record the highest temperature reached on the infrared thermometer, T for the filament.

Award 1 mark for:

8. The thermal energy supplied can be calculated by $E_{\text{thermal}} = m_{\text{water}} c \Delta\theta = m_{\text{water}} c \left(T_f - T_i\right)$, where c is the specific heat capacity of water which is a known constant.
9. The electrical energy input can be calculated using $E_{\text{input}} = I.V.t$ where t is the time taken to heat the water which is 5 min or 300 s.
10. The efficiency η can be calculated using $\eta = 1 - \dfrac{E_{\text{thermal}}}{E_{\text{input}}} = 1 - \dfrac{m_{\text{water}} c \left(T_f - T_i\right)}{I.V.t}$

Award 1 mark for:

11. Repeat steps 1 – 9 for another 9 different values of resistance across the variable resistor to obtain a total of 10 sets of readings for temperature of the filament lamp and efficiency i.e. (T, η)
12. Tabulate the values for temperature and efficiency.

Analysis Mark (Max: 2 marks)
[A1x2]

Award 1 mark for:

Plot a graph of lg η against lg T.
The relationship of $\eta = aT^b$ is valid if the plotted points follow the trend of a straight line graph.

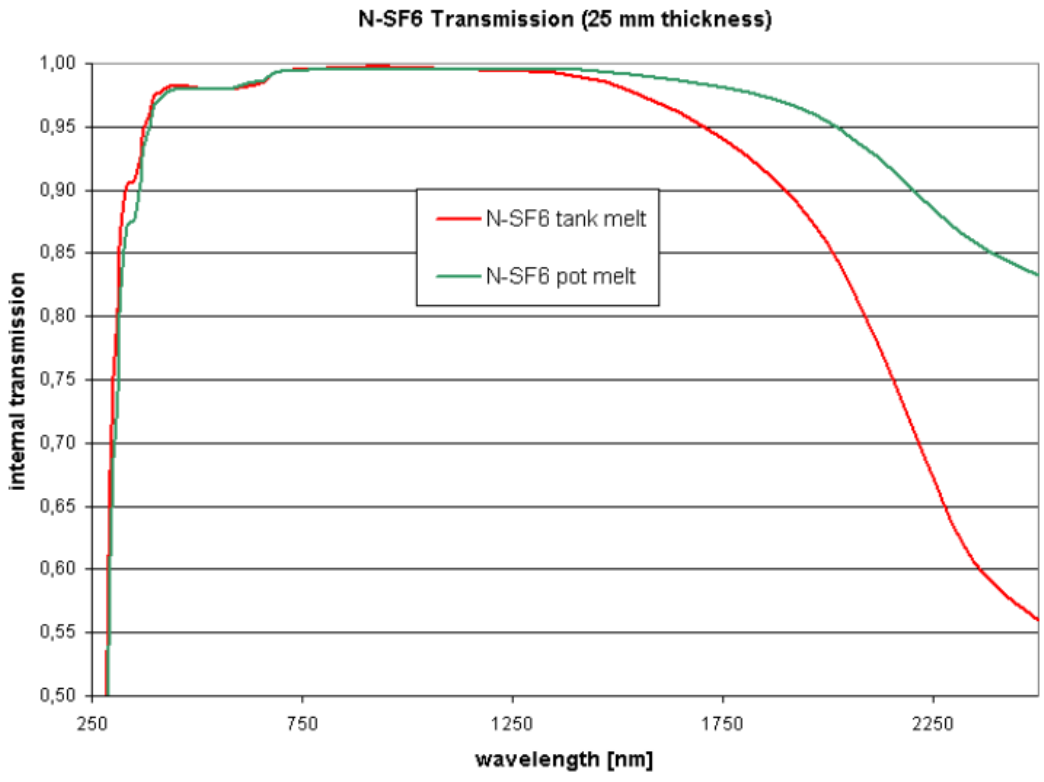
Award 1 mark for:

If the relationship is valid, then b can be determined from the gradient of the straight line graph, and
a can be calculated from the vertical intercept which is equal to *lg* a.

Reliability measures (Max: 2 marks)
[R1x2]

Any 2 of the following:

- Use a **stirrer to periodically stir** the water to ensure that the **water is of uniform temperature** before measuring the temperature.
- Place the **beaker of water in a styrofoam box** to **minimize heat loss to the surroundings**.
- *For stronger students*: the **wavelength used by the infra-red thermometer** must **not be absorbed by the glass bulb surrounding the filament**, this is ensured by **checking the IR wavelength used by the thermometer against the absorption or transmission spectrum of the glass bulb**.



The graph above is **an example of transmission spectrum for a type of glass** but made under two different conditions. If the filament is made using such a glass, the IR wavelength you would like to use on the IR thermometer would be from 800 nm – 100 nm where the transmission is almost 100%.

Safety Precautions [Max: 1 mark]
[S1]

- Use gloves when handling the hot beaker of water or adjusting the hot filament bulb to prevent being burned.

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9646/03

Paper 3 Longer Structured Questions **25 August 2016**

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 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 any **two** questions.

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	
1	/7
2	/9
3	/7
4	/7
5	/10
6	/20
7	/20
8	/20
Significant Figures	
Total	/**80**

This document consists of **22** printed pages.

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}
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	$= p\Delta V$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
hydrostatic pressure,	p	$= \rho gh$
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	$= v_o \cos \omega t$
		$= \pm\omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
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	$= x_o \sin\omega t$
transmission coefficient	T	$\propto \exp(-2kd)$
		where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{½}}$

Section A

For Examiner's Use

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

1 An Olympic ski jumper skis down a slope and launches off a cliff, landing on the ground a short time later. The mass of the ski jumper and his equipment is 80 kg.

Fig. 1.1 below shows the ski jumper just before he leaves the slope with a velocity of 20 m s^{-1} in the horizontal direction.

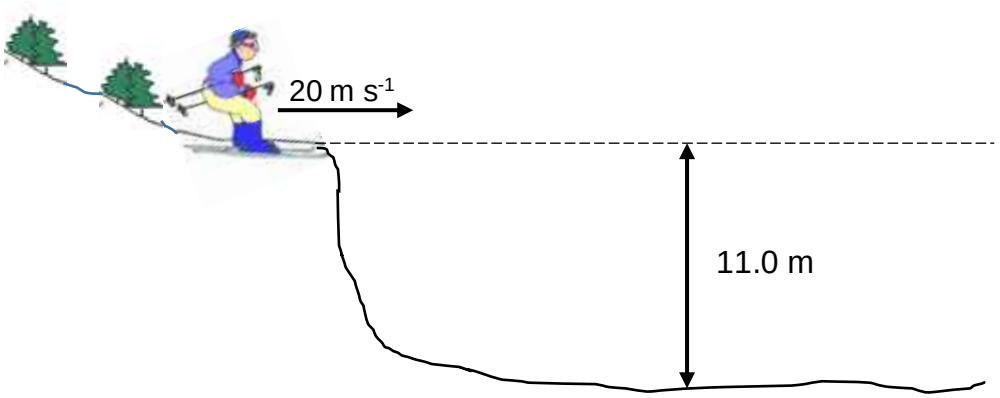


Fig 1.1

The ski jumper falls through a vertical distance of 11.0 m before landing on the ground.

(a) Calculate

(i) the time of flight of the ski jumper,

Taking downwards to be positive,
$s_y=u_yt + 0.5a_yt^2$
$11=0+0.5(9.81)t^2$
$t = 1.5$ s [A1]

time of flight = …….. s [1]

(ii) the horizontal distance travelled by the ski jumper during this time,

Assuming no resistance,
$s_x=u_xt = (20)(1.4975)$ [M1]$= 30$ m
allow e.c.f

horizontal distance = …….. m [1]

(iii) the velocity of the ski jumper just before he lands.

$v_y=u_y+a_yt$
$v_y=0+(9.81)(1.4975)$
$v_y=14.69$
v = sqrt(14.69 2+202)[M1]=24.8 m s-1 [A1]
tan(θ)= 14.69/20,
θ=36.3˚ [A1] (below horizontal)

			velocity = …… m s^{-1}	[2]
			direction: …… ^{o} below the horizontal	[1]
	(b)	By considering Newton's 2nd Law, explain how the snow covering the ground enables the ski jumper to land safely despite the high landing speed.		
		On landing, the snow gets compressed and this lengthens the time interval [B1]of the impact. By N2L, the average force experienced by the body is given by the rate of change in momentum i.e. F = dp/dt, hence the average impact force is lower allowing the ski jumper to land safely [B1] ……		
		……		
		……		
		……		[2]

For Examiner's Use

For Examiner's Use

2 (a) State Newton's law of gravitation.

1 (a) The gravitation force between 2 point masses is directly proportional to product of masses and inversely proportional to square of their separation. [A1]

……

…… [1]

(b) The Earth and the Moon may be considered to be isolated in space with their masses concentrated at their centres.

The orbit of the Moon around the Earth is circular, with a radius of 3.84×10^5 km. The period of the orbit is 27.3 days.

Show that

(i) the angular speed of the Moon in its orbit around the Earth is 2.66×10^{-6} rad s^{-1}.

ω=2π/T
ω=2π/(27.3 × 24 × 3600) [M1]
ω= 2.66 × 10-6 rad s-1 (shown) [A0]

[1]

(ii) the mass of the Earth is 6.0×10^{24} kg.

The gravitational force provides the centripetal force for the Moon. [M1]

$F_C = F_G$

$mr\omega^2 = \frac{GMm}{r^2}$

$r^3\omega^2 = GM$

$(3.84 \times 10^8)^3\omega^2 = G(\text{M})$ [M1]

$M = 6.0 \times 10^{24}$ kg [A0]

[2]

(c) The mass of the Moon is 7.4×10^{22} kg.

(i) Using data from **(b)**, determine the gravitational force between the Earth and the Moon.

$F_G = \frac{GMm}{r^2}$
$= (6.67 \times 10^{-11})(6.0 \times 10^{24})(7.4 \times 10^{22}) / (3.84 \times 10^8)^2$ [M1]
$= 2.0 \times 10^{20}$ N [A1]

force = …… N [2]

		(ii)	Tidal action on the Earth's surface causes the radius of the Moon's orbit to increase by 4.0 cm each year. Using your answer to **(c)(i)**, determine the change of the Moon's gravitational potential energy in one year. Explain your working.	
			ΔU = work done Since the question requires the use of answer in (i), we can assume that the gravitational force on Moon is constant during its small displacement of 4.0 cm. [M1] work done = F x = (2.0×10^{20}) (0.04) [M1] = 8.0×10^{18} J [A1] [Note: The other assumption is that the change in KE is zero.]	
			change in Moon's gravitational potential energy = …… J	[3]

For Examiner's Use

3 (a) A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by *simple harmonic motion*.

Acceleration proportional to displacement [C1]
Acceleration is in the opposite direction to its displacement [C1]

…… [2]

(b) The length of a pendulum l is measured to be 30.0 cm. The angular frequency of the simple pendulum is given by $\sqrt{\frac{g}{l}}$, where g is the acceleration of free fall. Determine the period of this simple pendulum.

Solution

Period, $T = 2\pi\sqrt{\frac{l}{g}}$

$= 2\pi\sqrt{\frac{0.30}{9.81}} = 1.10s$

[M1 for substitution, A1 for correct answer]

period = …….. s [2]

(c) A simple pendulum of period 1.90 s is set up alongside another pendulum of period 2.00 s. Both pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase.

Solution
Let n be the number of oscillations for pendulum of 2.00 s
Hence, for period of 1.90s will be (n + 1) number of oscillations. [C1]
When the two pendulum bobs are next in phase, they will be at the same stage of their oscillation. Each would have cover an integer no. of oscillations. although not the same no. of oscillations.
(n + 1) × 1.90 = n × 2.00 {M1}
gives n = 19 (oscillations of longer pendulum)
minimum time between in phase condition = 19 × 2.00 = 38 (s) [A1]

Or
Alternatively: In exam, MCQ, use LCM.
1.9 = (19/10) = (19)/10
2.0 = (20/10) = (20)/10
LCM of 1.9 & 2.0 = (20 x 19)/100 = 3.8 s.
Since the number of oscillations has to be an integer number, the number of oscillation has to be multiplied by 10 to 19 instead of 1.9. Hence time interval is 38.0 s

Or

For Examiner's Use

Let x be the time lapse before the 2 periods are in phase.
The difference between the number of oscillations must be 1.
$(x/1.9) - (x/2.0) = 1 \rightarrow x = 38$ s

Or
The phase difference of the 2 periods when they are next in phase is 2π rad.
Angular frequency of 2.0 s pendulum, $\omega = \pi$ rad s^{-1}.
Angular frequency of 1.9 s pendulum, $\omega = 1.0526\ \pi$ rad s^{-1}.
Difference of 2 angular frequencies of the pendulums is 0.0526π rad s^{-1}.
Hence, time lapse, $t = 2\pi / (0.0526\pi) = 38$ s

time interval = …….. s [3]

4 A long rope is held under tension between two points A and B. Point A is made to oscillate vertically and a wave is sent down the rope towards B as shown in Fig. 4.1.

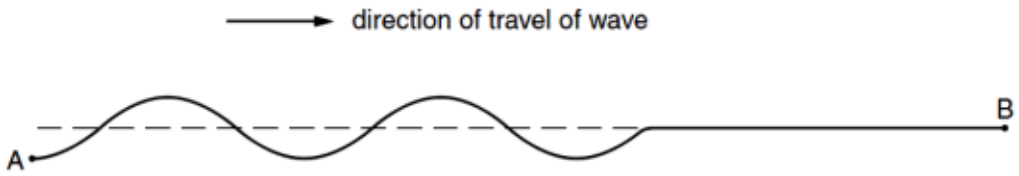


Fig. 4.1

The time for one oscillation of point A on the rope is 0.20 s. The point A moves a total distance of 80 mm during one oscillation. The wave on the rope has a wavelength of 1.5 m.

() (a) (i) Explain the term *displacement* for a particle in the wave, on the rope.

With reference to the wave on the rope, displacement is the **position** of a particle on the rope **with respect to the equilibrium point** during the course of the oscillation. [B1]

Accept: distance of a particle on the rope from the equilibrium / mean point during the oscillation.

Reject: distance travelled by a particle of the rope from the equilibrium / mean point during the oscillation. [1]

(ii) Calculate, for the wave on the rope,

1. the amplitude,

Total distance travelled by A after one oscillation = 80 mm.
Amplitude = 80 mm / 4 = 20 mm

amplitude = …….. mm [1]

2. the speed.

For Examiner's Use

frequency, f = 1/period, T

f = 1/0.20 = 5.0 Hz

v = f λ = (5.0)(1.5) [M1]
= 7.5 m s^{-1} [A1]

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

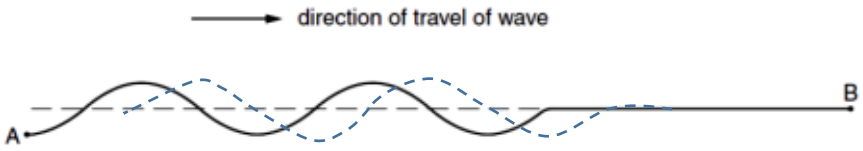
(b) Draw on Fig.4.1, the wave pattern on the rope at a time 0.050 s later than that shown.

[1]

$\frac{\Delta\lambda}{\lambda} = \frac{\Delta t}{T}$

$\frac{\Delta\lambda}{\lambda} = \frac{0.050}{0.20} = \frac{1}{4}$ $\Delta\lambda = \frac{1}{4}\lambda$

Thus, the waveform shifts to the right by a quarter of a wavelength. [B1]



(c) State and explain, whether the wave on the rope is

(i) progressive or stationary,

The wave is progressive because
- the wave profile (wave peak/trough) shifts to the right
- the energy of the wave is moving to the right

Any one of the above points [B1] [1]

(ii) longitudinal or transverse.

The wave is transverse because the plane of oscillation of the particles on the rope are perpendicular to the wave velocity. [B1] [1]

For Examiner's Use

5 **(a)** Fig. 5.1 below shows a filament lamp emitting white light, and is surrounded by a region of cooler helium gas.

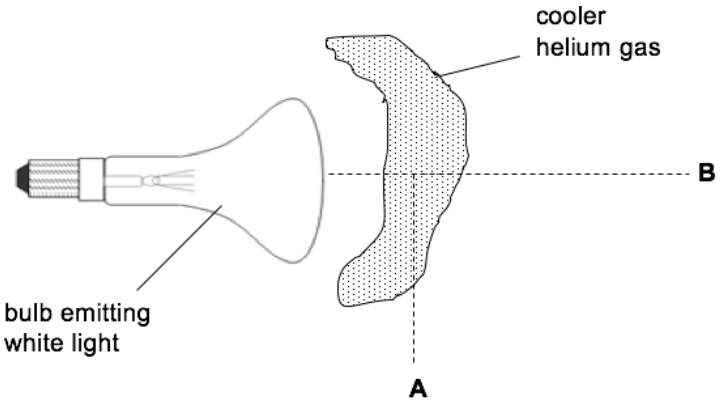


Fig. 5.1

(i) State if a helium *absorption* or *emission* spectrum is observed from

1. point A,

Emission [B1] [1]

2. point B.

Absorption [B1] [1]

(ii) Explain the formation of the helium spectrum observed from point A.

Bound helium electrons can only accept <u>photons which have the same energy as the difference in the helium's energy levels</u> [B1]

The excited electrons subsequently de-excite by <u>re-emitting photons of the same wavelengths as those that were previously absorbed.</u> However the <u>re-emission is in all directions</u> [hence the intensity of these photons on the screen at B is relatively lower resulting in a absorption spectrum]

When the detector is placed at A, it will detect the emitted photons from the excited He gas as it deexcites. Thus the spectrum at A is an emission spectrum i.e. Bright lines against a dark background. [B1]

…… [2]

(b) Fig. 5.2 shows some of the energy levels of an isolated helium atom.

For Examiner's Use

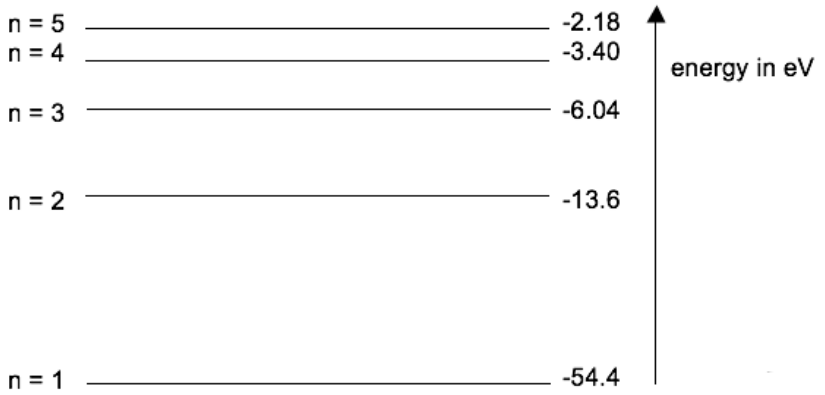


Fig. 5.2

An electron with a kinetic energy of 50 eV collides inelastically with a helium atom in the ground state.

(i) Draw, in Fig. 5.2, the possible downward transitions of the excited helium atom following this collision. [2]

Highest possible level is -6.04 eV

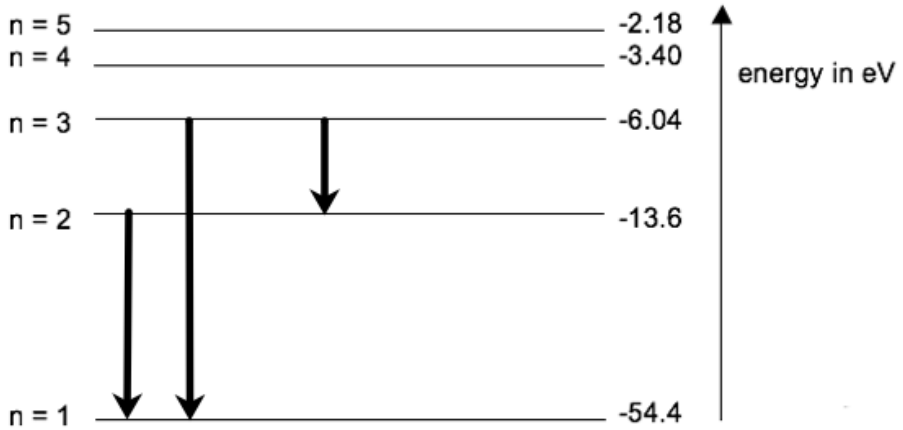


Fig. 4.2

All 3 transitions: B2
2 transitions: B1
0 or 1 transition: 0

(ii) Calculate the shortest wavelength of the radiation that is emitted from the transitions in **(b)(i).**

$$\Delta E = \frac{hc}{\lambda}$$

$$\left[-6.04-\left(-54.4\right)\right]\left(1.6\times10^{-19}\right)=\frac{6.63\times10^{-34}\left(3.0\times10^{8}\right)}{\lambda} \quad \text{M0}$$

$$\lambda = 2.57\times10^{-8}\ \text{m} \quad \text{A1}$$

			wavelength = …… m	[1]
		(iii)	Hence state the type of radiation for the wavelength calculated in **(b)(ii).**	
			Ultraviolet or UV [B1]	[1]
		(iv)	Explain what happens if UV photons of energy of 50 eV had been used to excite the ground state helium atoms instead 50 eV electrons.	
			A photon can only be absorbed completely or not at all. [M1] Since photon energy of 50 eV does not correspond to the difference of any of the energy levels, The photon is not absorbed and no upward emission subsequently [M1]	
				[2]

For Examiner's Use

Section B

For Examiner's Use

Answer **two** questions in this section.

6 (a) State Coulomb's law in electrostatics.

Coulomb's law states that the electrostatic force of interaction (attraction or repulsion) between two *point* electric charges is *directly proportional* to the *product* of the charges and *inversely proportional* to the *square* of the distance between them. [1]

(b) Fig. 6.1 shows two identical conducting spheres A and B, each carrying a charge of +*Q*. They are placed in a vacuum with their centres separated by a distance *d*, where *d* is of the same order of magnitude as the radii of the two spheres.

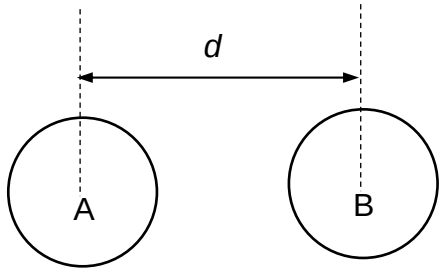


Fig. 6.1

Explain why the electric force, *F* between the two spheres is not given by the expression:

$$F = \frac{Q^2}{4\pi\varepsilon_o d^2}$$

The conducting spheres are not regarded as point charges. [B1]

The expression does not apply as the radii of the spheres are not very small compared to the separation *d* between the centres of the spheres. [B1] [2]

(c) An isolated conducting sphere R has a radius of 40.0 cm, and the charge on the sphere is +6.67 nC.

(i) Show that the potential on the surface of sphere R is 150 V.

$V=Q/(4\pi\varepsilon_o r)$ [C1]

$V=(9\times10^{9})(6.65\times10^{-9})/0.400$ [M1]

$V = 150$ V [A0]

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				[2]
		(ii)	A second conducting sphere S which is electrically neutral is now brought close to R. S has a radius 20.0 cm. A wire is used to connect the surface of sphere S to that of sphere R. After connecting, the charges will redistribute themselves between the surfaces of the two spheres until the potential on the surfaces of both spheres are the same. Show that $\frac{\text{final charge on S}}{\text{final charge on R}} = \frac{1}{2}$.
			After the wire is connected to the spheres, the charges will flow and quickly reach a state of equilibrium whereby the potential is constant. Let the final constant potential = V_f Since the spheres share the same final potential $V_R = V_S = V_f$ [C1] $\frac{Q'_R}{4\pi\varepsilon_o r_R} = \frac{Q'_S}{4\pi\varepsilon_o r_S}$ [M1] $\frac{Q'_S}{Q'_R} = \frac{r_S}{r_R} = \frac{0.200}{0.400} = \frac{1}{2}$ [A0]	
				[2]
		(iii)	Hence, determine the final electric potential on the surface of the two spheres.	
			Based on the principle of conservation of charges, $(Q_R + Q_S)$ initial = $(Q'_R + Q'_S)$ final $6.65\times10^{-9} + 0 = (Q'_R + Q'_S)$ …… Eqn (1) [B1] Substituting $Q'_R = 2\,Q'_S$ into Eqn(1) $3\,Q'_S = 6.65\times10^{-9}$ $Q'_S = 2.217\times10^{-9}$ C $V_f = \frac{Q'_S}{4\pi\varepsilon_o r_S}$ $= (9\times10^9)\frac{2.217\times10^{-9}}{(0.200)}$ [M1] $= 99.8$ V [A1] Accept 100 V as answer provided working is shown.	

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potential = ... V [3]

(d) Fig. 6.2 shows two parallel metal plates P and Q situated 8.0 cm apart in air.

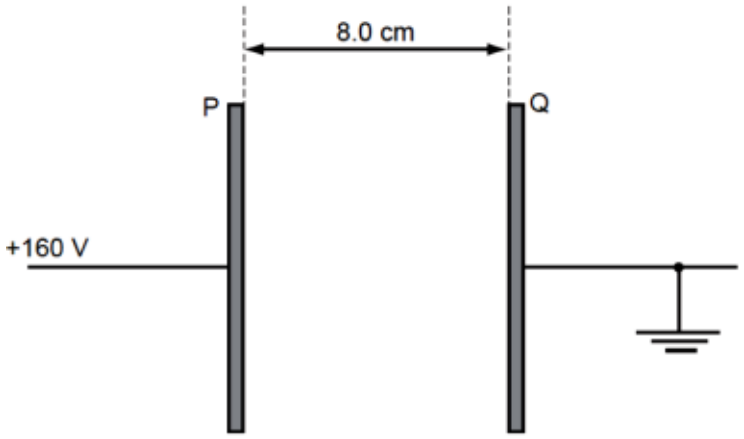

Fig. 6.2

Plate Q is earthed while plate P is maintained at a potential of +160 V.

(i) On Fig.6.2, draw lines to represent the electric field in the region between the plates.

[2]

Field lines perpendicular (normal) to the plates and equally spaced (at least 5 lines) [B1]
Direction is from P to Q.
[B1]

(ii) Show that the magnitude of the electric field strength between the plates is 2000 V m^{-1}.

[1]

$E = \frac{\Delta V}{d} = \frac{160-0}{0.080}$ [M1]

= 2 000 V m^{-1} [A0]

(iii) A dust particle is suspended in the air between the plates. The particle has charges of $+1.2\times10^{-15}$ C and -1.2×10^{-15} C near its ends.

The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 6.3.

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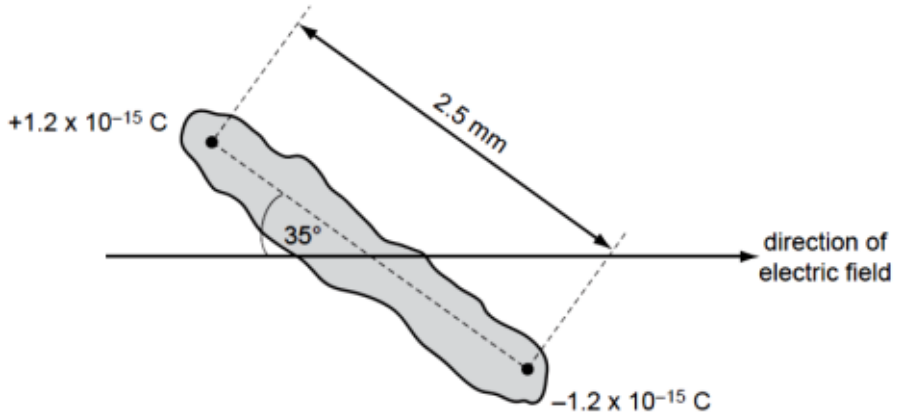
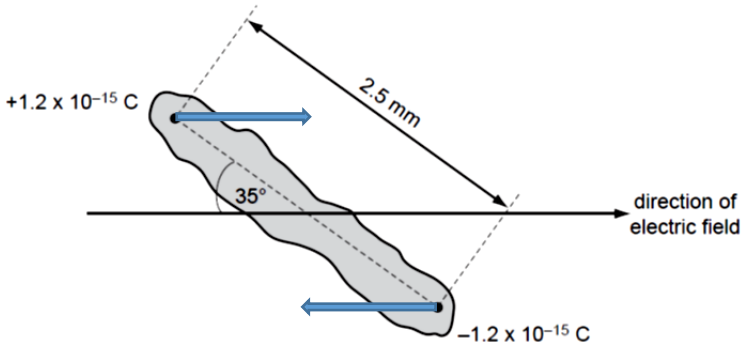


Fig. 6.3

The particle makes an angle of 35° with the direction of the electric field.

1. Draw on Fig.6.3, arrows to show the direction of the electric force on each charge due to the electric field.



For the positive charge, the direction of the force is horizontally to the right.
For the negative charge, the direction of the force is horizontally to the left.

The arrows should pass through the charges and the lengths should be approximately the same.

[1]

2. Calculate the magnitude of the electric force on each charge due to the electric field.

$F = E\,q$
$= (2000)(1.2\times10^{-15})$ [M1]
$= 2.4 \times 10^{-12}$ N [A1]

force = …… N [2]

3. Determine the magnitude of the couple acting on the particle at this instant.

				Couple = force × perpendicular separation = $(2.4 \times 10^{-12})(2.5\times10^{-3} \sin35^{o})$ [M1] = 3.44×10^{-15} N m [A1]	
				couple = …… N m	[2]
			4.	Suggest the subsequent motion of the particle in the electric field.	
				The particle will rotate clockwise (or oscillate about the equilibrium horizontal position) until it is aligned with the electric field. [B1] The positive end should be pointing towards the earthed plate. [B1]	[2]

For Examiner's Use

For Examiner's Use

7 (a) State what is meant by

(i) *nuclear binding energy*,

(a)(i) Accept either of the following from the lecture notes:

1. The ***binding energy*** of a *nucleus* is the energy required to **separate** to infinity all the nucleons of the nucleus (i.e. to become free **unbound** protons and neutrons). {A1}

2. The amount of energy that would be released if a nucleus were formed from separate protons and neutrons. [A1]

[1]

(ii) *nuclear fusion*.

From lecture notes: **Nuclear fusion** is a nuclear reaction in which two or more energetic light nuclei **combine** to produce a new heavier nucleus, with a release of energy. [A1]
'light' nuclei combine to form 'heavier' nuclei [A1]

[1]

(b) A possible reaction for use in a nuclear fusion reactor is one in which the deuterium and tritium nuclei fuse together to produce a helium nucleus.

Fig. 7.1 below shows the nuclear binding energies (BE) per nucleon for some particles.

particle	BE per nucleon / MeV
neutron, $^{1}_{0}n$	0
deuterium, $^{2}_{1}H$	1.11
tritium, $^{3}_{1}H$	2.83
helium, $^{4}_{2}He$	7.07

Fig. 7.1

(i) Complete the following nuclear equation to represent the fusion of the deuterium and tritium nuclei.

$$^{2}_{1}H + {}^{3}_{1}H \rightarrow \text{.....} + \text{.....} + \text{energy released}$$

Answer is Helium-4 & neutron [1]

(ii) Using values from Fig. 7.1, determine the energy released in the process in **b(i).**

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$\Delta E = BE_{products} - BE_{reactants}$

$= (7.07 \times 4) - [(1.11 \times 2) + (2.83 \times 3)]$ [M1]

$= 28.28 - 10.71$

$= 17.57$

≈ 17.6 MeV [A1]

energy released = …….. MeV [2]

(iii) Fig. 7.2 below shows the masses for the neutron and various

particle	mass / u
neutron, $^{1}_{0}n$	1.00867
deuterium, $^{2}_{1}H$	2.01356
tritium, $^{3}_{1}H$	3.01551
helium, $^{4}_{2}He$	4.00151

Fig. 7.2

By considering the change in mass during the nuclear fusion reaction, determine the energy released in the process in **(b)(i)**.

Solution
Mass defect = (2.01356 + 3.01551)u – (1.00867 + 4.00151)u
= 0.01889 u [M1]
Energy released = 0.01889 u x 931 MeV/u
= 17.6 MeV [A1]

Or
Energy released, $\Delta E = \Delta m\ c^2$
$= 0.01889 \text{ u} \times (3.0 \times 10^{8})^2$
$= 2.822 \times 10^{-12}$ J
= 17.6 MeV [A1]

energy released = …….. MeV [2]

(iv) Suggest why for nuclear fusion reactions to take place, high temperatures are required.

The deuterium and tritium nuclei are both positively charged and experiences electric repulsion. [1]

In order for fusion to occur, both nuclei must approach each other sufficiently close to tunnel through the coulomb barrier to fuse. [1]

Hence a higher temperature is needed, so that the nuclei would have a higher KE and would be able to approach each other close enough for fusion to take place. [1] [3]

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(v) In the doughnut-shaped Tokamak Fusion Test Reactor, the deuterium-tritium fuel can reach temperatures of up to 5.1×10^8 K, more than thirty times the core temperature of the sun.

No material can withstand the extreme temperature of the deuterium-tritium fuel.

Suggest one way of confining the deuterium-tritium fuel in the fusion reactor, without the walls of the reactor coming into contact with it.

Using a magnetic field [B1] the moving charged particles can be confined to a circular path [B1], without touching the walls of the reactor.

[2]

(vi) Suggest one advantage of nuclear fusion over nuclear fission as a means of energy production.

No risk of meltdown [B1] It is difficult enough to reach and maintain the precise conditions necessary for fusion—if any disturbance occurs, the plasma cools within seconds and the reaction stops. The quantity of fuel present in the vessel at any one time is enough for a few seconds only and there is no risk of a chain reaction.
Or
The **same quantity of fuel for nuclear fusion produces more energy** compared to the same mass of fuel for nuclear fission. [B1]
Or
Unlike nuclear fission, nuclear fusion reactors **produce no high activity, long-lived nuclear waste**. [B1]

…….....[1]

(c) The mass of a sample of Tritium is 1.0 g. The nuclide Tritium has a *half life* of 12.3 years.

(i) Define *half life* of a radioactive substance.

Half life is the average time taken for the activity of the substance to be halved.

[1]

(ii) Find the number of Tritium atoms in the sample.

Solution
Method 1
Number of atoms = (1.0 g ÷ 3.0 g) x 6.02 x 10^{23}
= 2.0 x 10^{23}. [A1]

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			Method 2 Mass of one atom = 3u = 3 x 1.67 x 10^{-27} Number of atoms = 1.0 x 10^{-3} ÷ (3 x 1.67 x 10^{-27}) = 2.0 x 10^{23} [A1]	
			number of Tritium atoms = ... atoms	[1]
		(iii)	Determine the decay constant for Tritium.	
			Solution Decay constant, λ = (0.693) ÷ (12.3 x 365 x 24 x 3600) [M1] = 1.79 x 10^{-9} [A1]	
			decay constant = ... s^{-1}	[2]
		(iv)	Calculate the fraction of Tritium atoms which remained after 20 years.	
			Solution $\frac{A}{Ao} = e^{-\lambda t}$ $\frac{A}{Ao} = e^{-\left(\frac{0.693}{12.3}\right)(20)}$ [M1 for formula] + [M1 for substitution] = 0.324 [A1]	
			fraction = ...	[3]

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8 **(a)** Define the *tesla*.

One tesla is defined as the magnetic flux density of a **uniform** magnetic field [B1], when a magnetic force per unit current per unit length of 1 newton per ampere per metre [B1] acts on a long, straight wire placed perpendicular to the magnetic field [B1]. [3]

(b) An electron is travelling with momentum p in a vacuum. It enters a region of uniform magnetic field of flux density 0.24 T, as shown in Fig. 8.1.

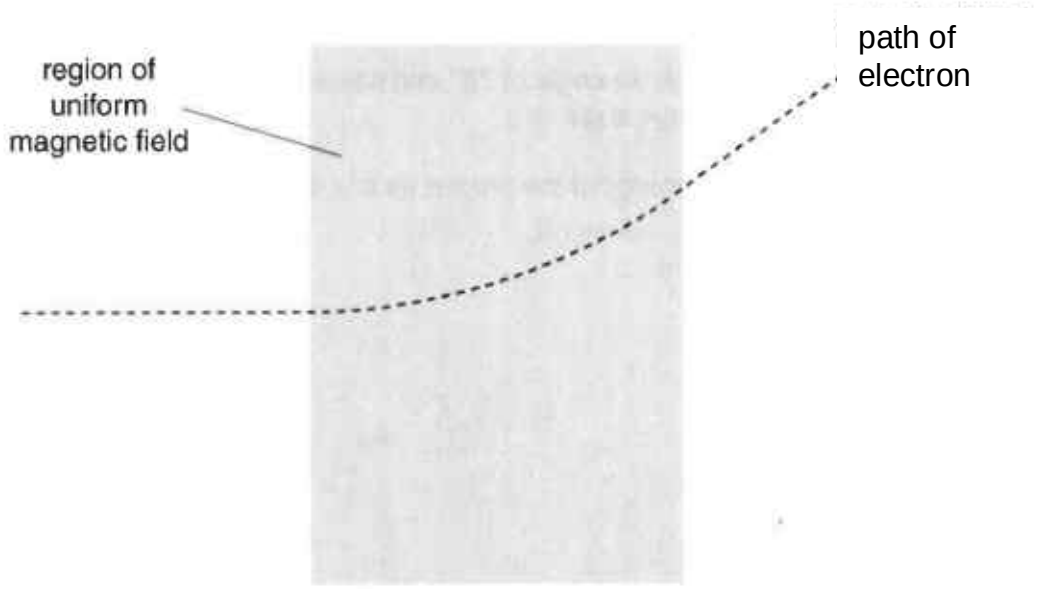

Fig. 8.1.

When the electron is in the magnetic field, it is travelling at right-angles to the direction of the field.

(i) Explain why the path of the electron in the magnetic field is an arc of a circle. [3]

1. The electron will **experience a magnetic force** when it enters the uniform magnetic field since it is **a moving charge in a magnetic field**. [B1]

2. The magnetic force will **act in the direction** that is **always perpendicular to the velocity of the charged particle [B1]**,

3. thus providing a **centripetal force [B1]** causing the particle to **travel in an arc of a circle**.

(ii) Draw in Fig. 8.1. the direction of the magnetic field. [1]

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Magnetic field directed out of the page. [B1]

(iii) The radius of the circular path of the electron in the magnetic field is 6.2 cm.

Calculate the momentum p of the electron.

The magnetic force experienced by the charged particle provides for the centripetal force, thus

$|F_B| = |F_C|$ [M1, statement explaining $|F_B|$ to $|F_C|$ must be included]

$$Bqv = \frac{mv^2}{r}$$

$$rBq = mv$$

$$p = rBq$$

$$= (0.062)(0.24)(1.6 \times 10^{-19}) \quad [M1]$$

$$= 2.38 \times 10^{-21} \text{ N s} \quad [A1]$$

p = …….. N s [3]

(c) Electrons are produced in beta decay. One example would be the beta decay of the Bismuth-210 nucleus to produce an electron and a Polonium-210 nucleus.

Fig. 8.2 below shows the tracks formed by the electron and the Polonium-210 nucleus, following the decay of an initially stationary Bismuth-210 nucleus, in a cloud chamber.

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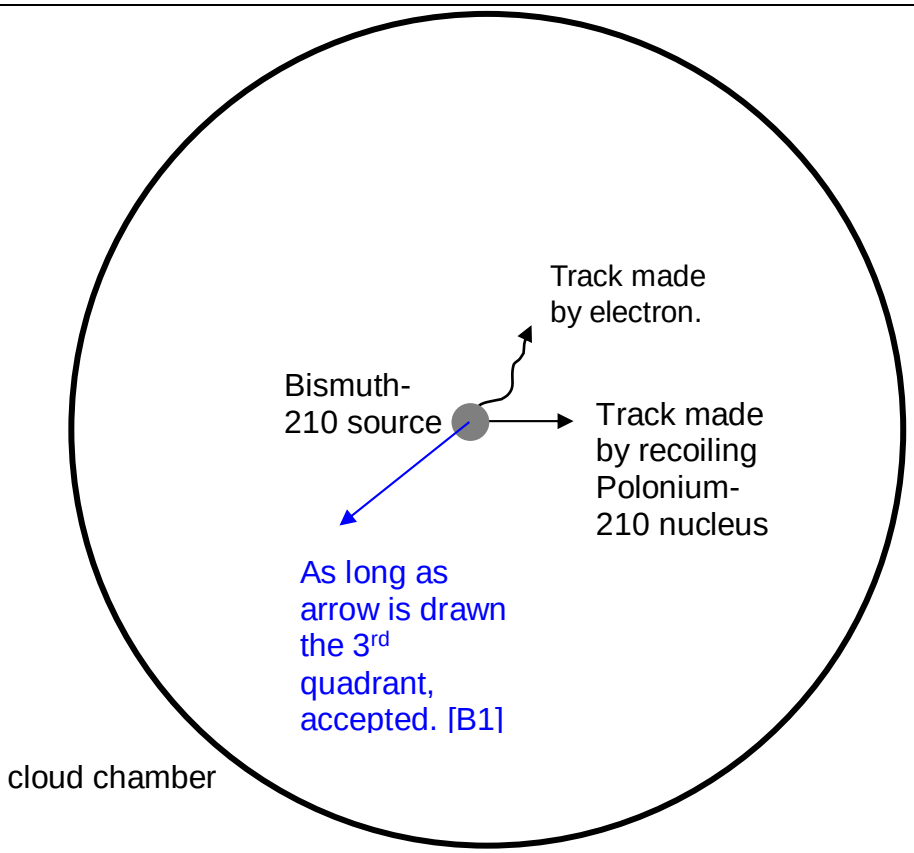

Fig. 8.2

(i) With reference to the directions of the cloud chamber tracks, and the principle of conservation of momentum, explain how a third particle (now known as the anti-neutrino) must have been formed despite not being seen in the cloud chamber.

1. The **initial momentum of the Bismuth 210 nucleus is 0** and by the **conservation of momentum**, we **expect the total momentum of the products to be zero** as well. [B1]

2. The **cloud chamber tracks show** the **direction** of the electron's and Polonium-210 nucleus's **velocities and hence, their momenta**. The **momenta** of the electron and the Polonium-210 nucleus are **not anti-parallel and thus will not add up to zero**. [B1]

3. Hence, **a third particle must have been produced** in **order for momentum to be conserved**. [B1]

[3]

(ii) Draw in Fig. 8.2. an arrow showing the path of the anti-neutrino. [1]

(d) An X-ray photon of wavelength 965.0×10^{-12} m collides elastically with a stationary

For Examiner's Use

electron, as illustrated in Fig. 8.3.

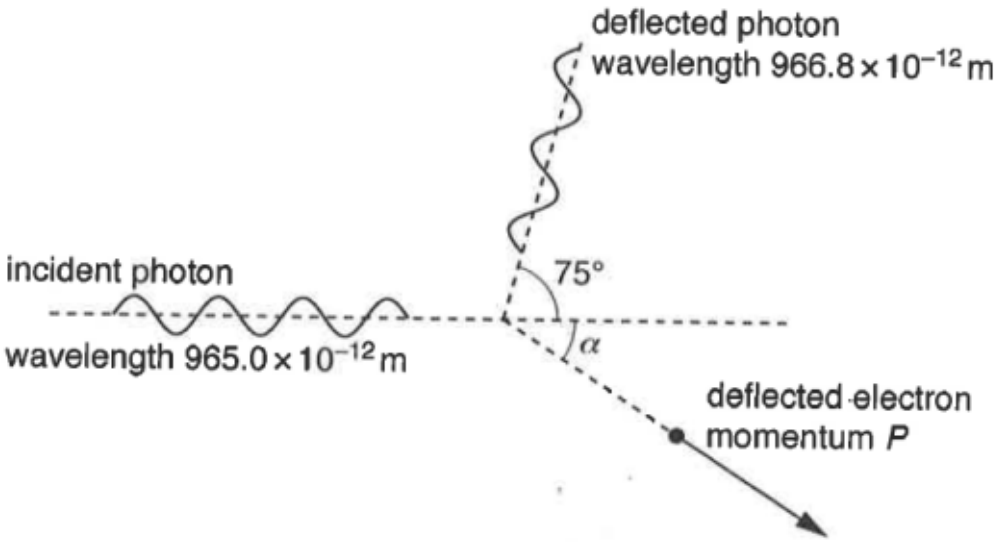

Fig. 8.3.

The photon is deflected through an angle of 75° and has a wavelength of 965.0×10^{-12} m. The electron is deflected through an angle α and has a momentum of 8.36×10^{-25} N s.

(i) Calculate the kinetic energy of the deflected electron.

Energy of deflected electron

$= E_{\text{incident photon}} - E_{\text{scattered photon}}$

$= \frac{hc}{\lambda_i} - \frac{hc}{\lambda_f}$

$= \left(6.63 \times 10^{-34}\right)\left(3.0 \times 10^{8}\right)\left(\frac{1}{965.0 \times 10^{-12}} - \frac{1}{966.8 \times 10^{-12}}\right)$ [M1]

$= 3.83 \times 10^{-19}$ J [A1]

kinetic energy = …….. J [2]

(ii) By considering the conservation of momentum or otherwise, calculate the angle of deflection, α of the electron in Fig. 8.3.

Explain your working.

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By the conservation of momentum along the vertical direction:

$\vec{P}_{\text{y, incident photon}} = \vec{P}_{\text{y, deflected photon}} + \vec{P}_{\text{y, deflected electron}}$ [M1, including explanation]

The total initial momentum along the vertical direction is 0 i.e.

$0 = \vec{P}_{\text{deflected photon}}\left(\sin 75^{\circ}\right) + \vec{P}_{\text{deflected electron}}\left(\sin\alpha\right)$

$0 = \left(+\frac{h}{966.8\times10^{-12}}\right)\left(\sin 75^{\circ}\right) + \left(-8.36\times10^{-25}\right)\left(\sin\alpha\right)$ [M1]

$\left(\frac{h}{966.8\times10^{-12}}\right)\left(\sin 75^{\circ}\right) = \left(8.36\times10^{-25}\right)\left(\sin\alpha\right)$

$\sin\alpha = 0.7923$ [M1]

$\alpha = 52.4^{\circ}$ or 127.5°

$\alpha = 52.4^{\circ}$

since α is less than 90° and momentum has to be conserved in the horizontal direction as well [M1]

angle α = ……. $^{\circ}$ [4]

Candidate Name: _____

Class	Adm No

H

millennia institute

2016 Preliminary Examination II

Pre-university 3

H2 PHYSICS **9646/01**

Paper 1 Multiple choices **23 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.

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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 What is the approximate volume of a typical inflated rubber party balloon?

A 0.001 m^3 **B** 0.01 m^3 **C** 0.1 m^3 **D** 1 m^3

2 In the determination of the electro-chemical equivalent, *z*, of copper by electrolysis, the following equation is employed:

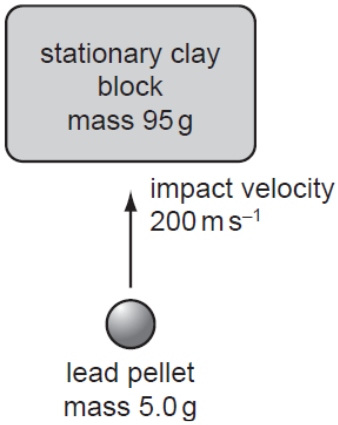
$$Z = \frac{m}{It}$$

m	= (3.99 ± 0.02) x 10^{-3} kg
$I \pm \Delta I$	= (2.00 ± 0.05) A
$t \pm \Delta t$	= (6000 ± 1) s

What is the percentage uncertainty of the value of z calculated from these readings?

A 2.5% **B** 2.8% **C** 3.0% **D** 3.3%

3 A lead pellet is shot vertically upwards into a clay block that is stationary at the moment of impact but is able to rise freely after impact. The mass of pellet is 5.0 g and the mass of clay block is 95 g.



The pellet hits the block with an initial velocity of 200 m s^{-1}. It embeds itself in the block and does not emerge.

How high above its initial position will the block rise?

A 5.1 m **B** 10.0 m **C** 61.0 m **D** 102.0 m

4 A trolley runs down a slope with a constant acceleration *a*. The mass of the trolley is now doubled and the trolley is allowed to run down the same slope. In both cases, effects of friction and air resistance are negligible.

Which statement is **correct** for the second experiment?

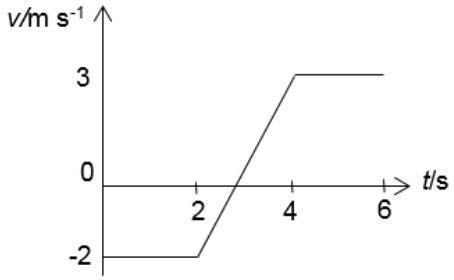
A The accelerating force is the same.

B The acceleration is $\frac{1}{2}a$.

C The acceleration is *a*.

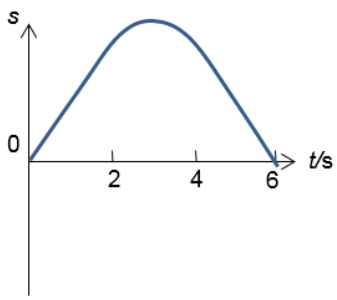
D The acceleration is 2*a*.

5 The figure below shows the velocity-time (*v* - *t*) graph of an object. At time *t* = 0 s, the object's displacement from the origin is 0 m.

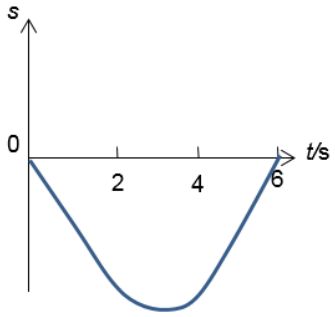


Which of the following best shows the corresponding displacement versus time (*s* - *t*) graph of the object?

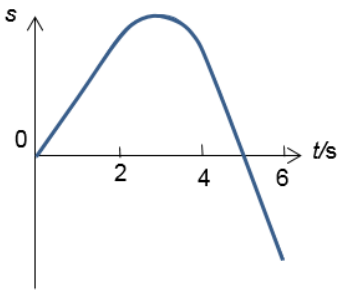
A



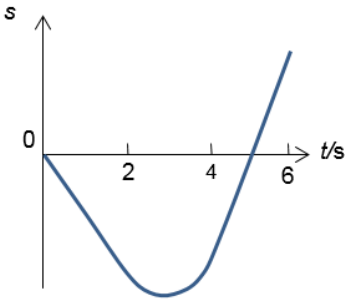
B



C



D

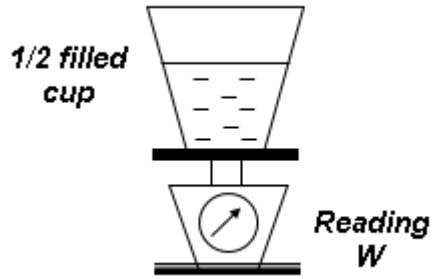


6 A metal ball is dropped from rest over a bed of sand. It hits the sand 2.0 seconds later and makes an depression of up to 2.5 cm deep in the sand. Assume air resistance is negligible.

On hitting the sand, what is the average deceleration of the ball?

A 7.7×10^3 m s^{-2} **B** 12.5 m s^{-2} **C** 7.7 m s^{-2} **D** 0.0125 m s^{-2}

7 A cup half-filled with water resting on a weighing scale registers a reading *W*. When a boy dips his finger into the water without touching the base, the reading of the weighing scale is *W'*.



Which of the following statements is correct?

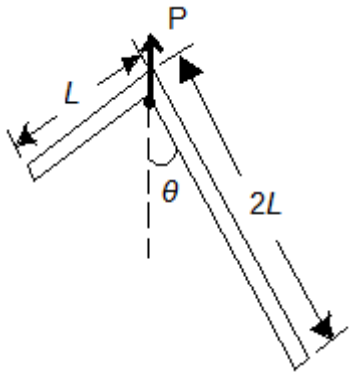
A *W'* = *W* because the water has not overflowed from the beaker.

B *W'* < *W* because the water exerts an upthrust on the boy's finger.

C *W'* > *W* because the water exerts an upthrust on the boy's finger and as a result, the boy's finger exerts a force back on the water.

D *W'* > *W* because the weight of the boy's finger is added to that of the water in the beaker.

8 A right-angle rule hangs at rest from a peg P as shown below. It is made from a metal sheet of uniform density. One arm is *L* cm long while the other is 2*L* cm long.

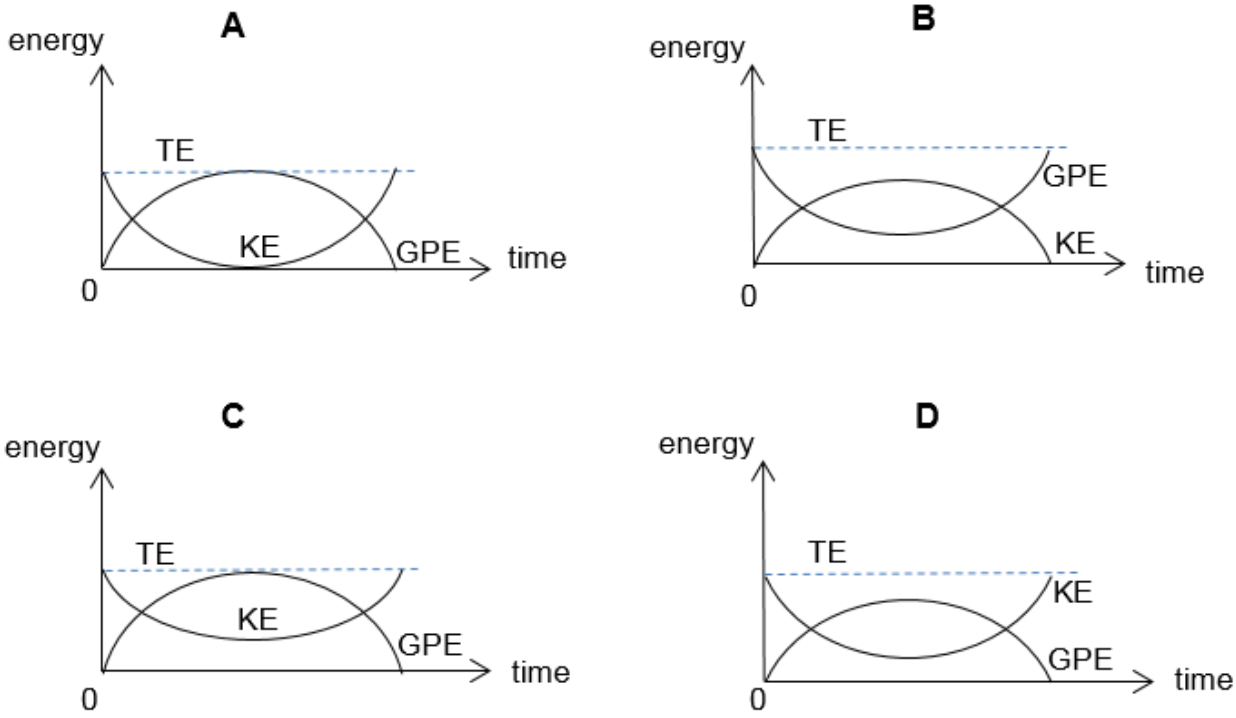


What is the angle *θ* at which it will hang in equilibrium?

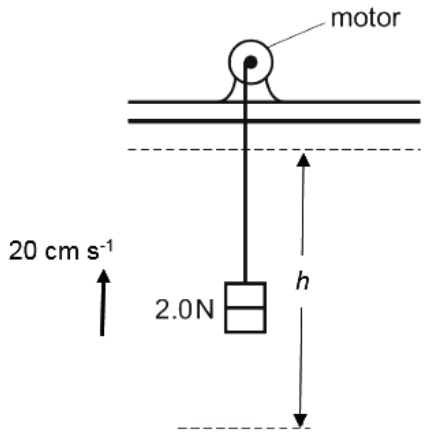
A 8° **B** 14° **C** 42° **D** 76°

9 A ball is thrown at an angle above the horizontal. It lands on the ground after travelling a certain distance. Air resistance is negligible. Assume GPE to be zero at ground level.

Which of the following best shows the correct gravitational potential energy (GPE), kinetic energy (KE) and total energy (TE) graphs for the ball?



10 A small electric motor is used to raise a weight of 2.0 N at a constant speed of 20 cm s^{-1} through a certain height *h*.



The efficiency of the motor is 20 %.

What is the electrical power supplied to the motor?

A 200 W **B** 2.0 W **C** 0.80 W **D** 0.080 W

11 An artificial satellite travels in a circular orbit about the Earth. Its rocket engine is then fired and produces a force on the satellite exactly equal and opposite to that exerted by the Earth's gravitational field.

In which direction will the satellite then start to move?

A Along a spiral path towards Earth

B Along the line joining it to the centre of the Earth (i.e. radially)

C Along a tangent to the orbit

D In a circular orbit with a longer period

12 Which of the following statements is **not true** for a stone attached to a string and swung in a uniform vertical circular motion?

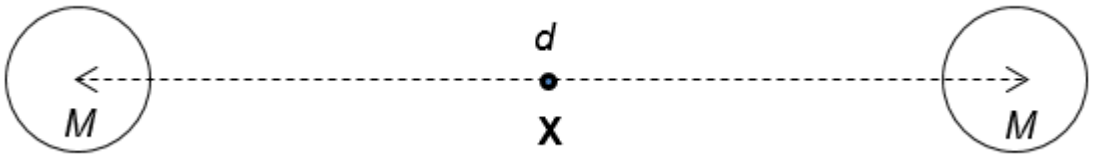
A The magnitude of resultant force acting on the stone changes depending on the position of the stone in the circle.

B The tension in the string is lowest when the stone is at the highest point of the circular motion.

C The kinetic energy of the stone is constant throughout the entire circular motion.

D The resultant acceleration is always directed towards the centre of the circle.

13 The centers of two isolated spherical stars each of mass M and radius R are separated by a distance d as shown.



Point **X** is mid-way between the stars.

Which expression gives the gravitational potential at point **X** due to the two stars?

A zero **B** $-\frac{2GM}{d}$ **C** $-\frac{4GM}{d}$ **D** $-\frac{GM}{R}$

14 The moon orbits the Earth once every 27.3 days, with a mean orbital radius of R.



What is the period of a satellite orbiting with a radius of $\frac{R}{30}$ from the centre of the Earth?

A 0.17 hours **B** 4.0 hours **C** 68 hours **D** 260 hours

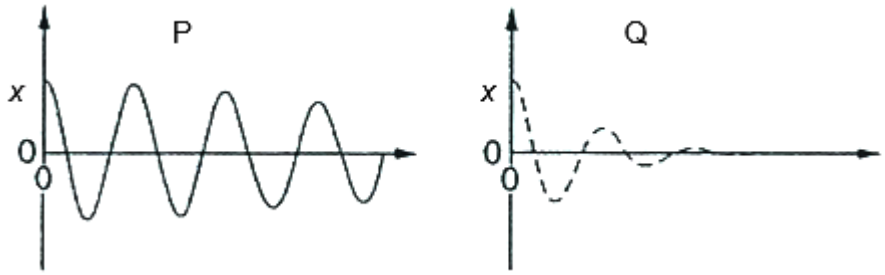
15 An object placed on a horizontal platform is vibrating vertically in simple harmonic motion with a frequency of 2.0 Hz.

The amplitude of vibration of the platform is gradually increased from zero. At one particular amplitude, the object is seen to lose contact with the platform.

What is the amplitude of the oscillation when this occurs?

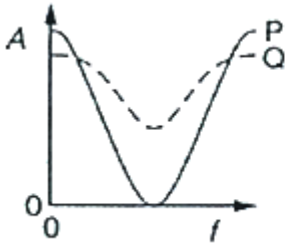
A 3.9 cm **B** 6.2 cm **C** 7.8 cm **D** 12.4 cm

16 Two objects P and Q are given the same initial displacement and are then released.
The graphs show the variation with time t of their displacement x.

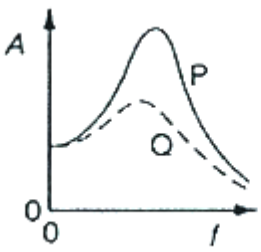


The graphs below show the amplitudes during forced oscillations at different frequencies.
Which graph represents the variation with f of the amplitudes A of P and of Q?

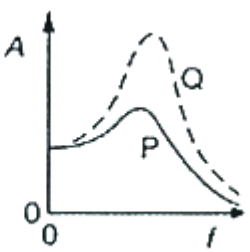
A



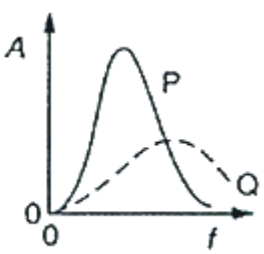
B



C



D



17 Four different solids **P**, **Q**, **R** and **S** of equal mass M at 20 °C, are separately heated at the *same rate*. Their melting points and specific heat capacities are as shown in the table below.

Solid	Melting point / °C	Specific heat capacity / J kg^{-1} K^{-1}
P	80	1200
Q	100	800
R	150	600
S	300	250

Which of these solids will start to melt first?

A P **B** Q **C** R **D** S

18 80 J of energy is supplied to an ideal gas of volume 2.0×10^{-3} m^3 and at pressure of 1.0×10^5 Pa. The volume increases to 2.2×10^{-3} m^3, while the pressure remains constant.

What is the change in the internal energy of the gas?

A - 60 J **B** 60 J **C** 100 J **D** 220 J

19 A transverse wave of wavelength 6.28 m travels in a stretched string. The displacement y of particles along the stretched string with time is given by the expression

$$y = 10\sin\left(\frac{t}{0.02}\right)$$

Given that t is in second(s) and y in (m), what is the speed of the wave?

A 50.0 m s^{-1} **B** 40.0 m s^{-1} **C** 5.00 m s^{-1} **D** 4.00 m s^{-1}

20 A diffraction grating has 625 lines per mm. A beam of light is incident normally on the grating. The first order maximum makes an angle of 20° with the undeviated beam.

What is the wavelength of the incident light?

A 550 nm **B** 420 nm **C** 270nm **D** 210 nm

21 Which of the following statements is correct?

A Coherent sources are not needed to produce interference fringes.

B Two coherent light sources do not always produce bright and totally dark fringes on a screen.

C The atoms in a tungsten filament lamp produce coherent light waves.

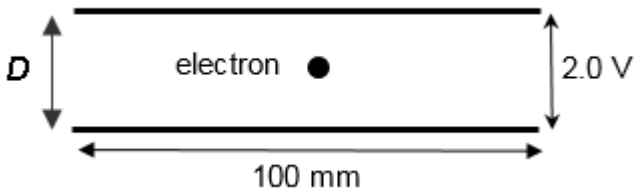
D The yellow light from a street lamp is coherent light.

22 In a two-slit interference experiment, one slit transmits waves of twice the amplitude compared to the other slit. The maximum intensity of the interference pattern is I_o.

What is the minimum intensity of the pattern?

A zero **B** $\frac{I_o}{2}$ **C** $\frac{I_o}{4}$ **D** $\frac{I_o}{9}$

23 Two horizontal metal plates, each of length 100 mm, are separated by a distance ***D*** as shown. The potential difference between the two plates is 2.0 V.



The electron situated between the two plates experiences an electric force of 6.4×10^{-16} N upwards.

What are the direction of the electric field and the distance between the two plates, ***D***?

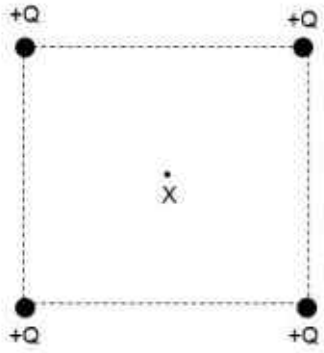
A Upwards, 0.25 mm

B Upwards, 0.50 mm

C Downwards, 0.25 mm

D Downwards, 0.50 mm

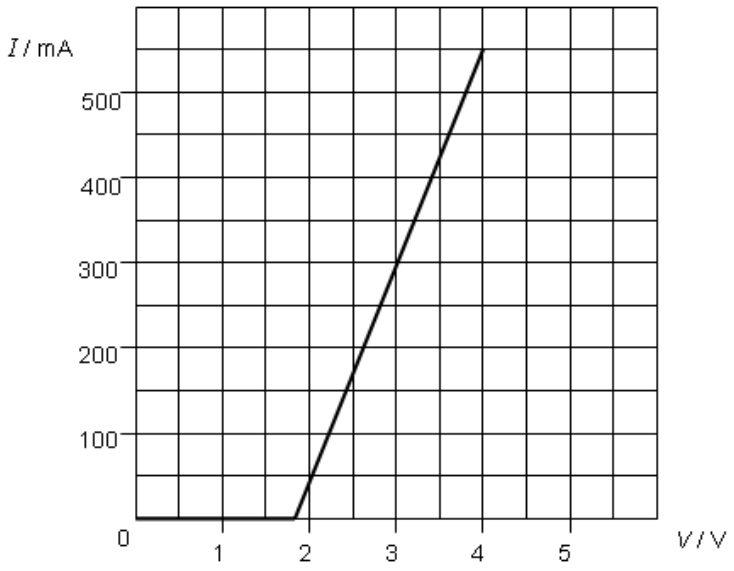
24 Four identical point charges are arranged at the corners of a square as shown.



Which statement is true about the electric field strength *E* and the electric potential *V* at the centre X of the square?

	E	*V*
A	not zero	zero
B	not zero	not zero
C	zero	not zero
D	zero	zero

25 The diagram shows the relation between the current *I* in a circuit element and the potential difference *V* across it.



Which statement about the circuit element is correct?

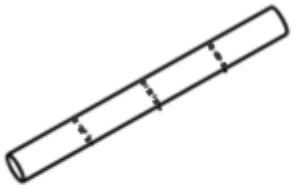
A It does not obey Ohm's law but when $V > 1.8$ V, its resistance is constant.

B It does not obey Ohm's law and when $V > 1.8$ V, its resistance is not constant.

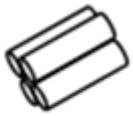
C It obeys Ohm's law and when $V > 1.8$ V, its resistance is constant.

D It obeys Ohm's law but when $V > 1.8$ V, its resistance is not constant.

26 A length of wire is cut into four equal parts and these parts are then wrapped together side by side to make a thicker wire.



original wire

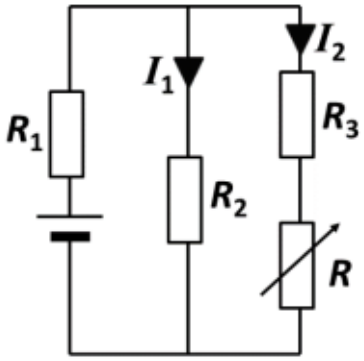


new thicker wire

What is the ratio of the resistance of the original wire to this new thicker wire?

A 16:1 **B** 4:1 **C** 1:4 **D** 1:1

27 In the circuit below, $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_3}$ are fixed resistors and **R** is a variable resistor.



How will I_1 and I_2 vary as **R** decreases?

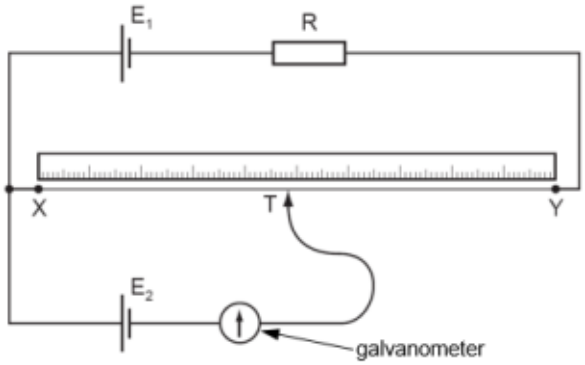
A I_1 remains unchanged, and I_2 increases.

B I_1 decreases, and I_2 remains unchanged.

C I_1 decreases, and I_2 increases.

D I_1 decreases, and I_2 decreases.

28 The diagram below shows a potentiometer circuit. The values of E_1, E_2, R, and length XT were initially unknown.



The contact T is placed on the wire and moved along the wire until the galvanometer reading is zero. The length XT is then noted.

In order to calculate the potential difference per unit length of the wire XY, which value must also be known?

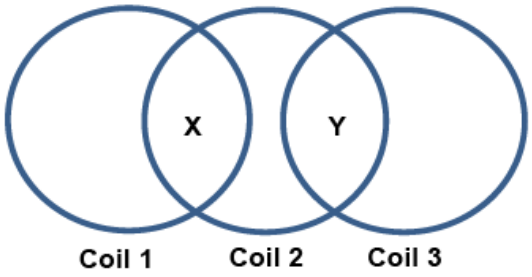
A the e.m.f. of the cell E_1

B the e.m.f. of the cell E_2

C the resistance of resistor R

D the resistance of the wire XY

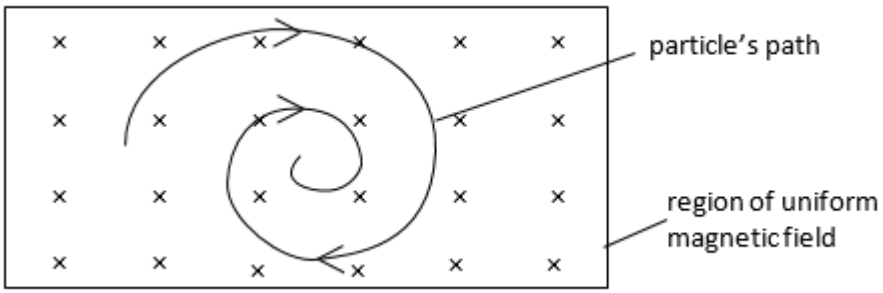
29 Three coils are interlinked such that there are overlapping regions. Each of the coils carries identical current but their directions are unknown. Region X is found to have a magnetic flux density of near zero while region Y is found to have a resultant magnetic field pointing out of the paper.



Which of the following is a possible configuration of the direction of flow of the currents in the coils?

	Coil 1	**Coil 2**	**Coil 3**
A	Clockwise	Clockwise	Counter-clockwise
B	Clockwise	Counter-clockwise	Counter-clockwise
C	Counter-clockwise	Clockwise	Clockwise
D	Counter-clockwise	Counter-clockwise	Clockwise

30 The figure below shows a region of uniform magnetic field directed into the page. A charged particle moving in the plane of the page follows a clockwise spiral path of decreasing radius as shown.



Which of the following best describes the particle?

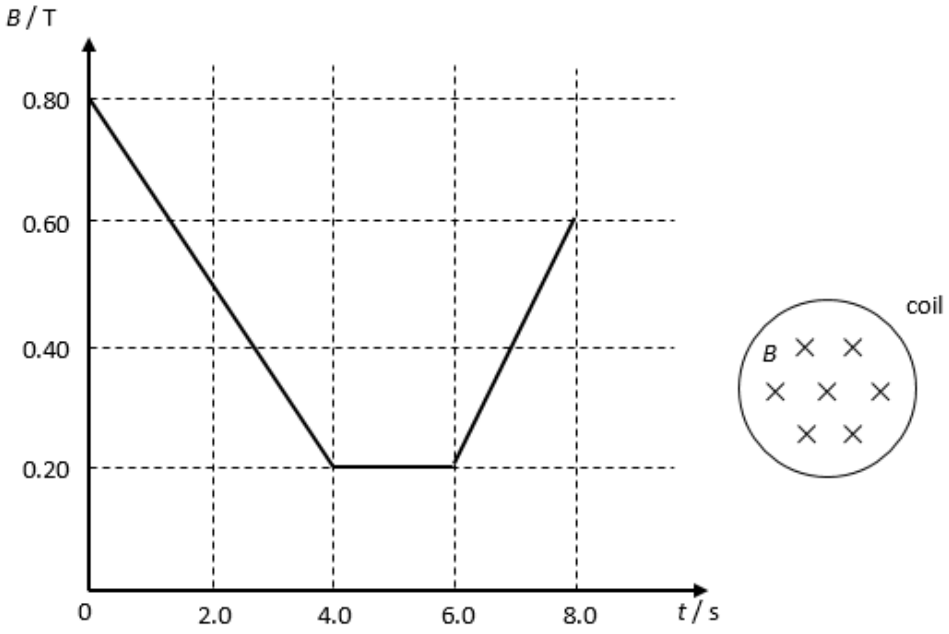
A Negatively charged and slowing down.

B Positively charged and slowing down.

C Positively charged and speeding up.

D Negatively charged and speeding up.

31 A one-turn coil of wire of area 0.20 m^2 and resistance 0.25 Ω is placed with its plane perpendicular to a magnetic field that varies with time as shown below.



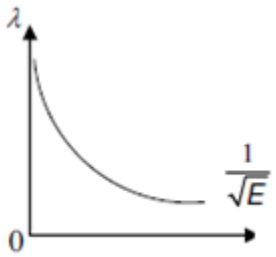
What is the largest possible induced current flowing in the coil?

A 0.12 A **B** 0.16 A **C** 0.28 A **D** 1.6 A

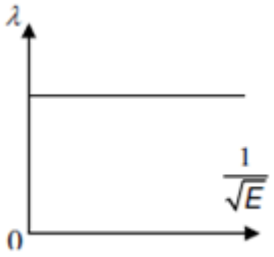
32 An electron with kinetic energy *E* has a de Broglie wavelength of λ.

Which of the following graphs correctly represents the relationship between λ and E?

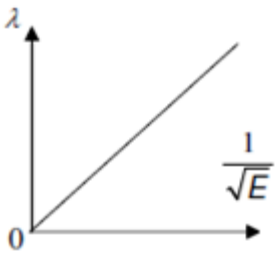
A



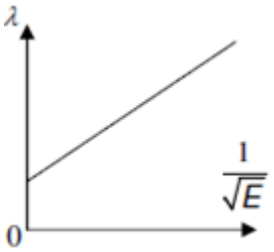
B



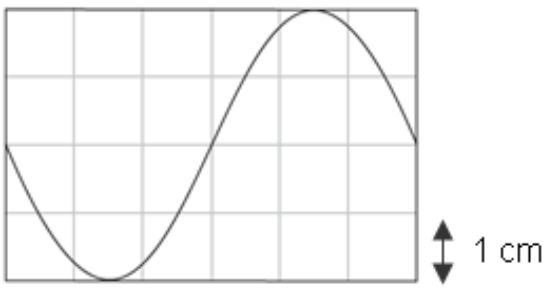
C



D



33 An alternating current passes through a resistor *R* of resistance 10 Ω. The potential difference across the resistor is measured by a cathode-ray oscilloscope (c.r.o.). The figure below shows the waveform on the screen.

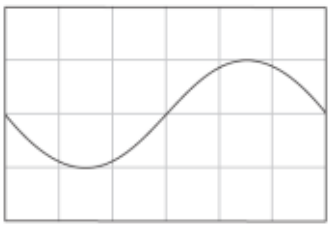


The y-sensitivity of the c.r.o. is 2.0 V cm^{-1}.

What is the average power dissipated in the resistor?

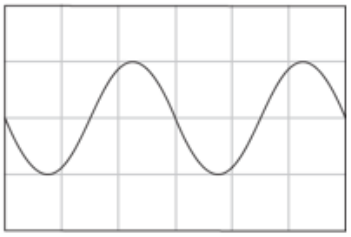
A 0 W **B** 0.40 W **C** 0.80 W **D** 1.6 W

34 An ideal transformer has n turns in the primary coil and 2n turns inn the secondary coil.
The waveform produced on the screen of a cathode-ray oscilloscope (c.r.o.), when the c.r.o. is connected to the primary coil, is shown below.

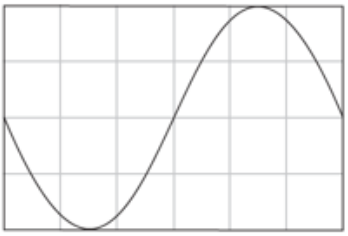


Which of the following diagrams shows the waveform displayed on the c.r.o. when it is connected to the secondary coil without any changes made to the settings?

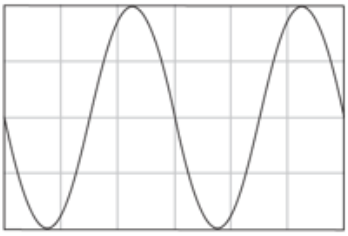
A



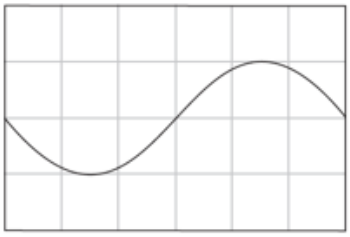
B



C



D



35 In a photoelectric experiment, a parallel beam of monochromatic light is incident on a cathode having a work function of 2.06 eV.
When a graph of photocurrent against voltage is plotted, the stopping potential obtained is 0.70 V.

What is the energy of a photon from this light source?

A 1.10×10^{-19} J **B** 3.30×10^{-19} J **C** 4.42×10^{-19} J **D** 6.60×10^{-19} J

36 A simple model of the energy levels in an atom has only three levels; **X**, **Y** and **Z**. A transition from level **X** to level **Z** produces radiation of wavelength 280 nm; a transition from level **Y** to level **Z** produces a radiation of wavelength 200 nm.

Which of the following deductions concerning this system of three energy levels is **correct**?

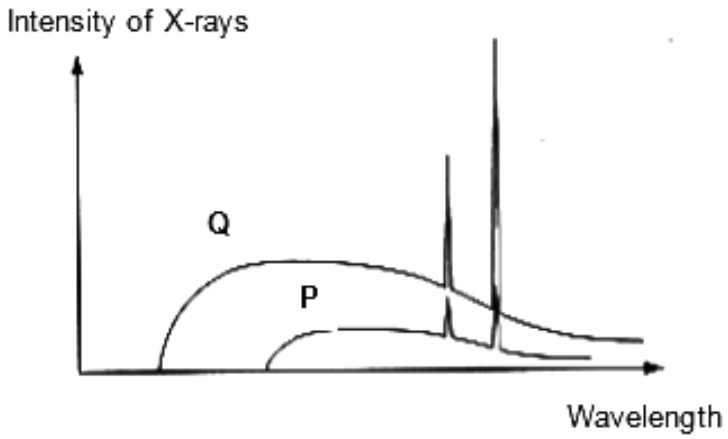
A The wavelength of radiation emitted in a transition between levels **X** and **Y** is 80 nm.

B The wavelength of radiation absorbed in a transition between levels **X** and **Y** is 80 nm.

C Level **Y** has a greater energy than levels **X** or **Z**

D Levels **X** has a greater energy than levels **Y** or **Z**

37 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 is the same.

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

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.

38 Which statement about an ideal intrinsic semiconductor is **correct**?

A It can behave like an insulator at low temperature.

B The donor energy level lies just below the conduction band.

C There are equal number of electrons in the valence band and the holes in the conduction band.

D There is an energy gap of 5 eV to 10 eV between the valence and conduction band.

39 Two deuterium nuclei fuse together to form the Helium-3 nucleus, with the release of a neutron. The reaction is represented by

$$ {}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n + \text{energy} $$

The binding energies per nucleon are:

for ${}^{2}_{1}H$ 1.09 MeV
for ${}^{3}_{2}He$ 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

40 A radioactive source consists of 64×10^{12} atoms of nuclei *P* of half-life 2 days. Another source consists of 8×10^{12} atoms of nuclide *Q* of half-life 3 days.

After how long will the number of active nuclei in the two sources be equal?

(Assume that the daughter nuclides of both *P* and *Q* are stable.)

A 6 days **B** 9 days **C** 12 days **D** 18 days

End of Paper

Candidate Name: _____

Class	Adm No

H

millennia institute

2016 Preliminary Examination II
Pre-university 3

H2 Physics **9646/02**
Paper 2 Structured Questions

Friday **16 September 2016** **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	
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4	
5	
6	
7	
8	
Total	

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) State the conditions for a body in equilibrium.

……

……

…… [2]

(b) Fig. 1 below shows a girl supported by two elastic ropes. She is in equilibrium and her weight is 392 N.

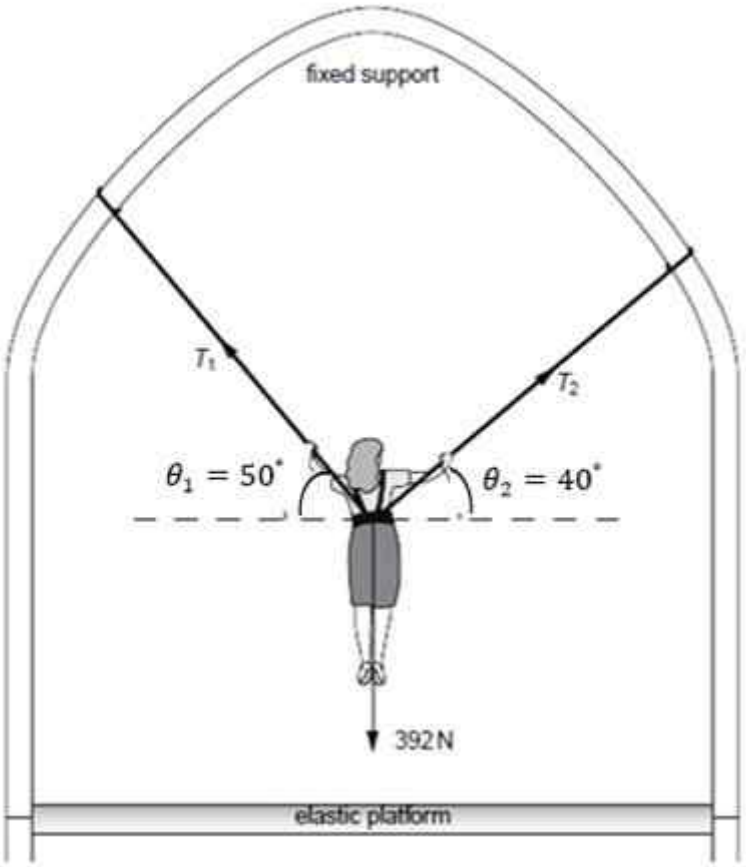

Fig. 1

(i) Determine the tensions T_1 and T_2 in the two ropes.

T_1 = …… N

T_2 = …… N [3]

(ii) Suggest if it is possible to tighten the ropes so tightly such that the angles of the ropes and the horizontal, θ_1 and θ_2 are zero.

……

……

……[2]

(iii) The girl is pulled vertically downwards so that the ropes stretch. She is then released. Discuss without further calculation whether the method you used in **(i)** could be used to determine the tensions in the ropes immediately after she is released.

……

……

……[2]

2 A cable car carries a mass M of 95 kg through a vertical height, as shown in Fig. 2.

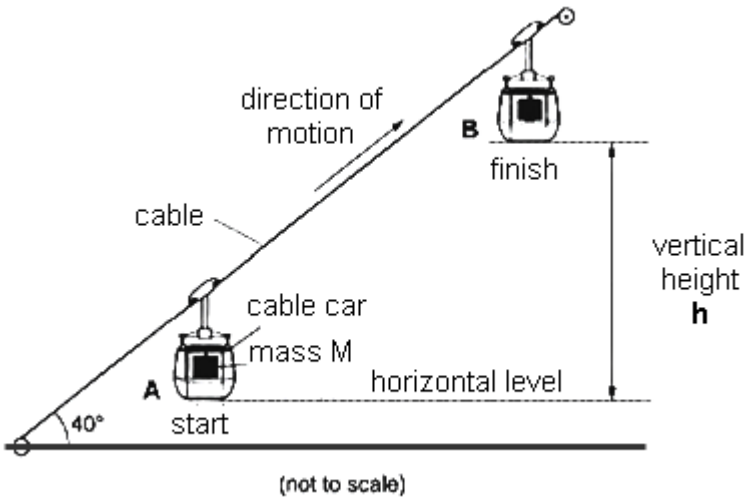

Fig. 2

The cable car is attached to a cable and moves at an angle of 40° to the horizontal. Initially, the cable car starts from rest at A and accelerates at 0.5 m s^{-2} along the cable for a time of 3.0 s. The cable car then moves at constant speed of 1.5 m s^{-1} for 100 s until it reaches B. The floor of the cable car is horizontal at all times.

(a) Calculate the distance moved along the cable by mass M during the initial acceleration.

distance moved = …….. m [2]

(b) Calculate the gain in potential energy of the mass M during the acceleration.

gain in potential energy = …….. kJ [2]

(c) The vertical height *h* of the mass M varies with time *t.* On the axe below, show qualitatively the variation with time *t* of height *h* for the motion of the mass M from A to B.



[2]

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3 (a) Define gravitational field strength.

…….....

…….....[1]

(b) Two stars A and B of equal masses are in circular orbit about a common centre as shown in Fig. 3.

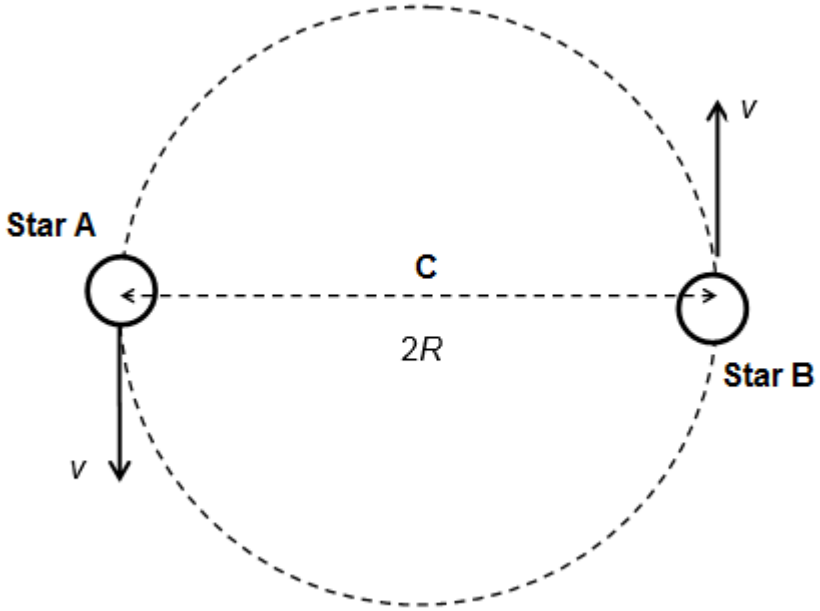

Fig. 3

The mass of each star is M and their separation is $2R$. The speed of each star is v.

(i) Draw an arrow on Fig. 3 to show the direction of acceleration of star A.
Label this arrow Y. [1]

(ii) Explain the reason for the direction of acceleration of star A in **(b) (i).**

…….....

…….....

…….....

…….....[2]

(iii) Draw an arrow on Fig. 3 to show the direction of the gravitational field due to star B at C, the midpoint between the stars. Label this arrow Z.

[1]

(c) A satellite is orbiting around the Earth of mass 5.98×10^{24} kg. Calculate the Earth's gravitational field strength of the satellite at distance 4.22×10^{7} m from the centre of the Earth.

gravitational field strength = ……N kg $^{-1}$ [2]

(d) Explain why an astronaut in a satellite orbiting the Earth may be described as "weightless".

……

……..[1]

4 (a) Fig. 4.1 shows the variation of displacement with position at a particular instant for a progressive sound wave travelling in air.

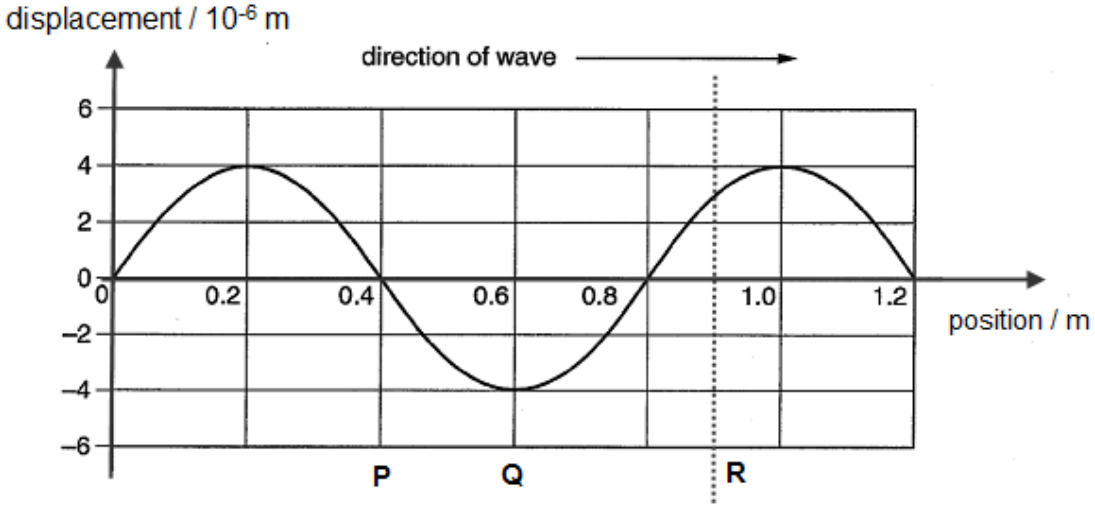

Fig. 4.1

(i) **1.** State one way in which the motion of an air particle at position Q is *similar to* the motion of an air particle at position P as the wave passes.

……[1]

2. State one way in which the motion of an air particle at position Q is *different from* the motion of an air particle at position P as the wave passes.

……[1]

(ii) The speed of the sound wave is 340 m s^{-1}. Calculate the frequency of the sound wave.

frequency = ……Hz [2]

(iii) The intensity of sound waves at position Q is 10 W m^{-2}.
Calculate the intensity of sound waves at position R.

intensity at R = …… W m^{-2} [2]

(b) A microwave transmitter is positioned directly opposite a microwave detector which is connected to a meter as shown in Fig. 4.2.

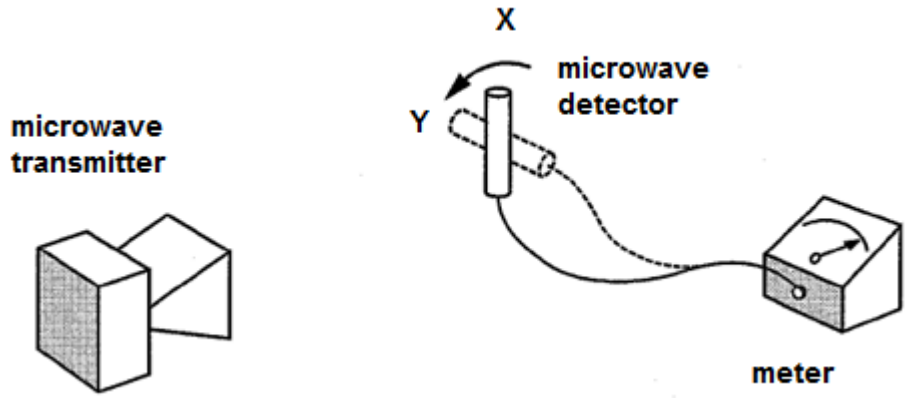

Fig. 4.2

(i) State how the transmission of microwaves in air is different from sound waves.

……

…… [1]

(ii) Initially the meter shows a maximum reading when the detector is at position X. When the detector is rotated through 90° to position Y (Fig.4.2), in vertical plane as shown, the meter reading falls to zero.

Explain why the meter reading falls when it is at position Y.

……

……

……

…… [2]

5 (a) Alpha particles, each of mass 4.0 u, are accelerated from rest in a narrow horizontal beam through a potential difference of 1.5×10^6 V. The alpha particles then enter the region of the y-plates as shown in Fig. 5.1.

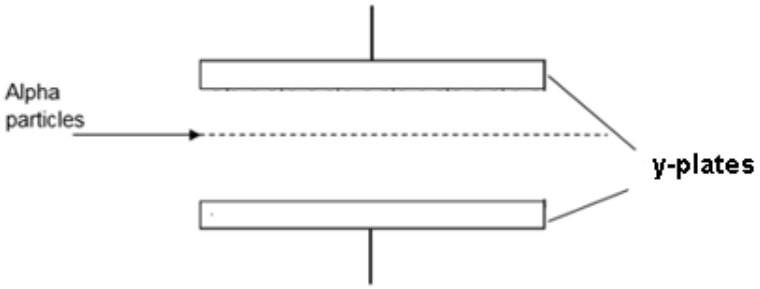

Fig. 5.1

When there is no electric field between the y-plates, the beam will pass through un-deflected.
Show that the velocity of the alpha particles that enters the region of the y-plates is 1.2×10^7 m s^{-1}. [2]

(b) The y-plates are 25 cm long and 12 cm apart. An uniform electric field of magnitude 3.8×10^6 N C^{-1} is now applied between the two plates as shown in Fig. 5.2.

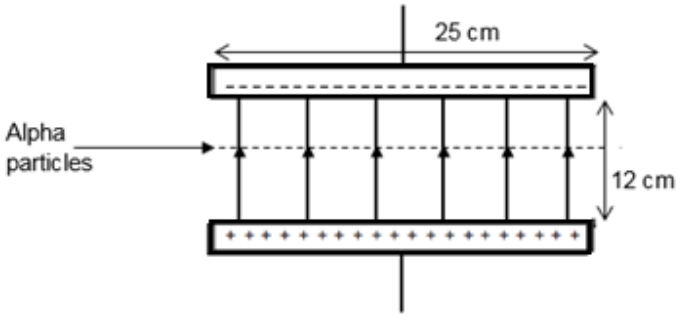

Fig. 5.2

Explain why the alpha particles do not move in a straight line through the uniform electric field but along a parabolic path.

……

……

……

……[2]

(c) To enable the alpha particles to pass through un-deflected, a magnetic field can be placed perpendicularly to the existing electric field.

With reference to Fig. 5.2, determine the direction of the magnetic field and the magnetic flux density that enables the alpha particles to pass through un-deflected again.

magnetic flux density = ……..…… T [2]

direction: ……..…….…… [1]

6 **(a)** Fig. 6 shows some energy levels, in eV, of an atom, not drawn to scale.

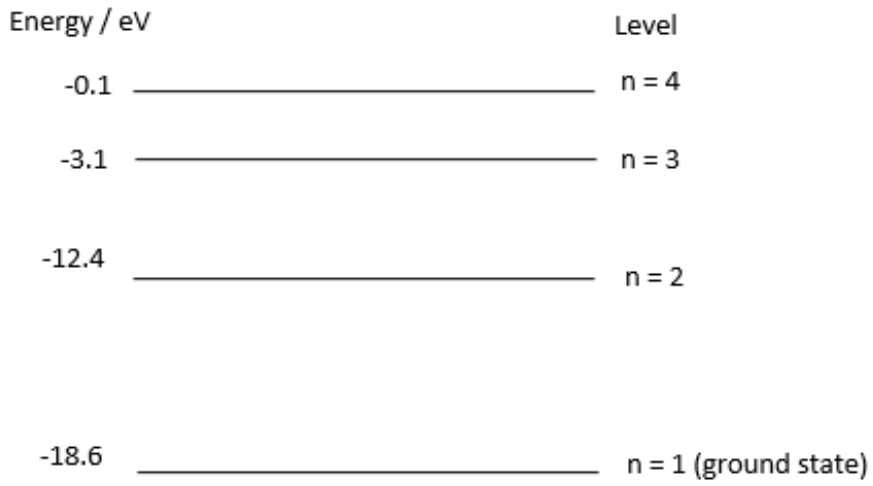

Fig. 6

Photons of specific wavelengths are emitted from these atoms when they are excited by collisions with electrons.

(i) Explain why the emitted photons have specific wavelengths.

……

……

……[1]

(ii) One of the emitted photons has an energy of 9.92×10^{-19} J.

Calculate the wavelength of this photon.

wavelength = …….. m [2]

(b) By drawing an energy band diagram, describe how the number of mobile charge carriers of an intrinsic semiconductor is affected by p-type doping.

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……[3]

7 The circuit in Fig. 7.1 is used for an experiment to determine Planck's constant.

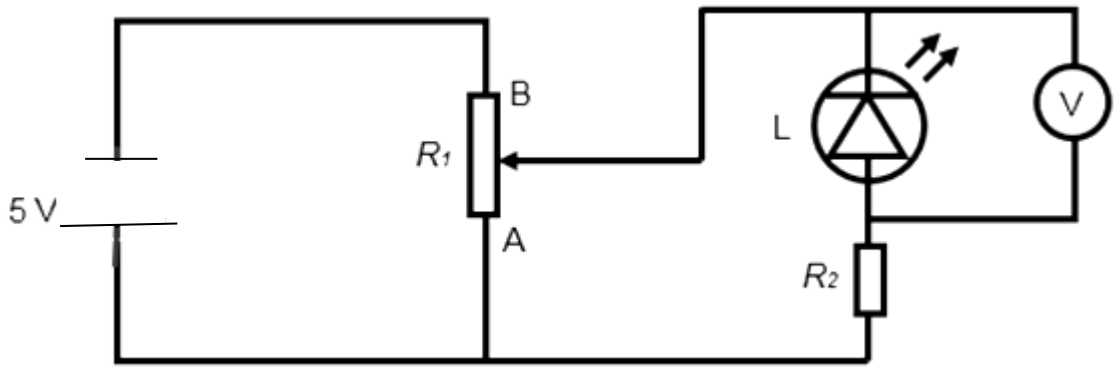

Fig. 7.1

A Light-Emitting Diode (LED) that gives off red light of wavelength 695 nm is used for component L. As contact point at resistor R1 shifts from A to B, the reading across the voltmeter also varies.

Initially, the red LED light did not light up, it was only when the voltmeter reached a reading of V_0 did it light up. V_0 was then recorded. L was then replaced with LEDs that gave off infrared light of wavelength 1000 nm, yellow light of wavelength 660 nm and green light of wavelength 630 nm.

The data collected is as shown in table in Fig. 7.2.

LED	V_0 **/ V**	λ **/ nm**	λ^{-1} **/ nm^{-1}**
Infrared	0.866	1000	
Red	1.367	695	
Yellow	1.464	660	
Green	1.560	630	

Fig. 7.2

(a) Fill in the missing data in column on λ^{-1} in Fig. 7.2. [1]

(b) Plot a graph of V_0 against λ^{-1} on the grids in Fig. 7.3. [3]

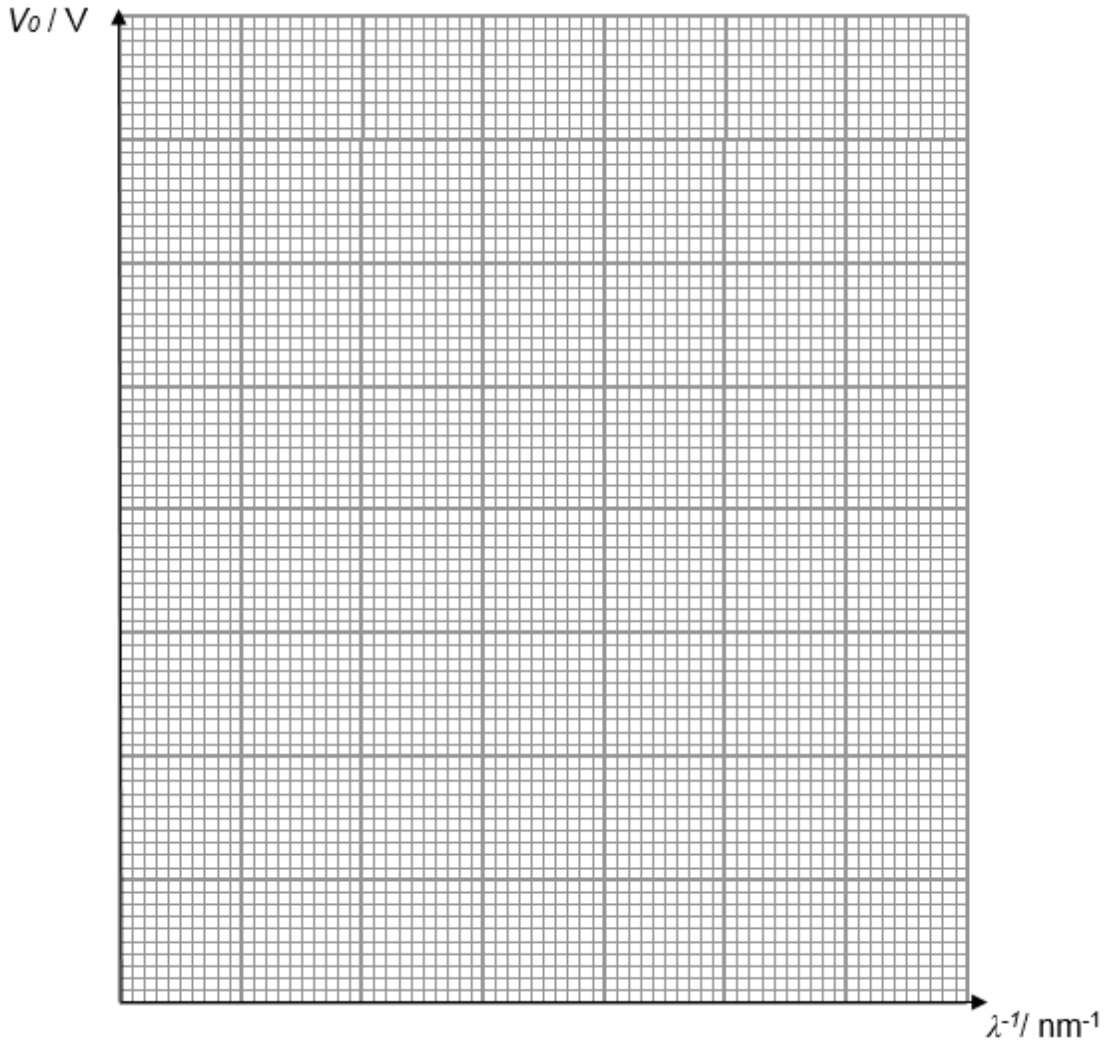

Fig. 7.3

(c) State the energy which is required for an electron to move across the LED in terms of elementary charge e and voltage across the LED V_0.

……

……[1]

(d) The energy of each photon corresponds to the energy stated in **(c).**
Show how Planck's constant can be determined from the graph in Fig. 7.3. [2]

(e) Determine Planck's constant from the graph in Fig. 7.3.

Planck's constant = …… J s [3]

(f) Suggest two possible reasons for the difference between the calculated Planck's constant from graph in Fig. 7.3 and the theoretical value for Planck's constant.

……

……

……[2]

(g) When electrons and holes in a P-N Junction recombine, light will be emitted.
With this information, suggest how photons of specific wavelengths are formed in the LED when the circuit is closed.

……

……

……[2]

(h) Using the table in Fig. 7.2, determine the energy gap between the conduction and valence band of the infrared LED.

energy gap = …… J [1]

Section B (12 Marks)

It is recommended that you spend about 30 minutes on this section.

8 The absorption of light as it passes through a transparent material varies with the refractive index of material used. The refractive index of a material determines how much light is bent, or refracted, when entering a material.The intensity *I* of light passing out of the material varies with the refractive index R of transparent material used.

You are provided with a meter to measure the intensity of light and transparent slides made with different refractive indices. You may also use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the relationship between *I* and the given refractive indices R of different materials through which light passes through.

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 *I* and *R* is determined from your readings,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

DIAGRAM

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Class Adm No

Candidate Name: _____

H

millennia institute

2016 Preliminary Examination II

Pre-university 3

H2 Physics **9646/03**

Paper 3 Longer Structured Questions

Tuesday **20 Sep 2016** **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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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	
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Total	

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
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acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

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		=	$\pm \omega\sqrt{(x_o^2 - x^2)}$
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,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
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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	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Section A

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

1 (a) An object is thrown vertically upwards with initial velocity 10 m s^{-1} near the surface of Earth.
Sketch labelled graphs on the axes below to show how **(i)** the acceleration, and **(ii)** the velocity of the object, varies with time. Air resistance can be neglected.

Mark on the graphs the time, t_1, at which the object reaches maximum height and the time, t_2, at which it returns to its original position.

[3]

(i)



(ii)



(b) When air resistance is **not** negligible, the object will experience drag force in motion.

Sketch on the velocity-time graph in **(a)(ii)** above, how the velocity of the object varies with time when air resistance is present. Label this sketch **B**. [2]

(c) A water fountain shoots a jet of water at 5.0 m s^{-1} towards a target a distance away as shown in Fig 1.1. Air resistance can be neglected.

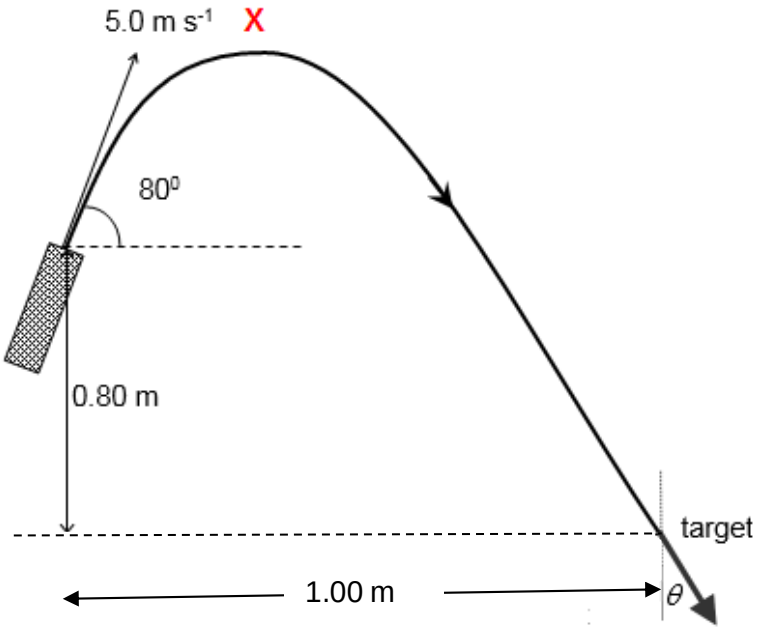

Fig. 1.1

(i) State and explain the magnitude of the acceleration of the water at the top of the trajectory at X.

……

……

…… [2]

(ii) Show that the angle θ at which the water strikes the target is 8^0. [2]

2 A water-wheel has eight buckets equally spaced around its circumference as shown in Fig 2.

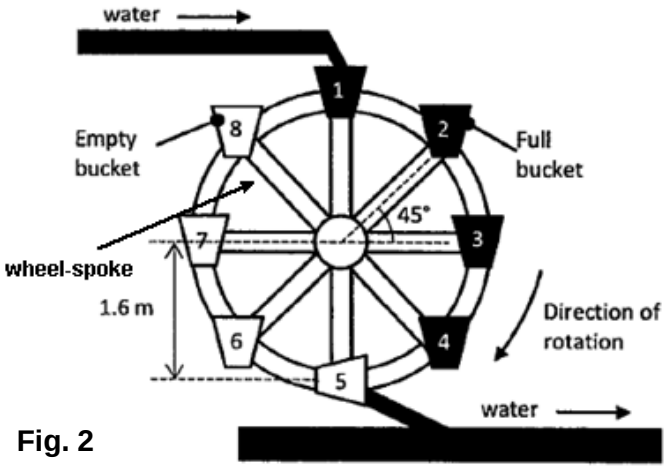

Fig. 2

Distance between centre of each bucket and centre of wheel =1.6 m
Total mass of bucket filled with water when it is at the highest level = 40 kg
The water-wheel takes 90 s to make 3 complete revolutions.

(a) Calculate the angular velocity of the water-wheel.

angular velocity = ……rad s^{-1} [2]

(b) Calculate the magnitude the force needed to move bucket 1 in a circular path.

centripetal force = …….. N [2]

(c) Explain why a force is required to move bucket 1 in a circular path.

……

……

…… [2]

(d) State and explain whether the magnitudes of the centripetal force acting on bucket 1 and bucket 5 are the same.

……

……

…… [2]

[Turn over

3 Fig. 3 shows two microwave transmitters A and B placed 0.20 m apart. The transmitters emit microwaves of equal amplitude in phase and of wavelength 30 mm. A detector, moved along the line PQ at a distance of 5.0 m from AB, detects regions of high and low intensity forming an interference pattern.

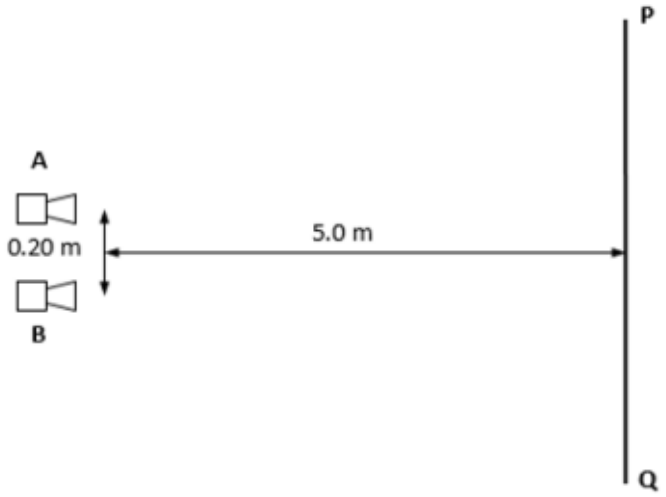

Fig. 3

(a) Calculate the separation between one region of high intensity and the next along the line PQ.

separation = ... m [2]

(b) Describe and explain the effect, if any, on the position and intensity of the maxima when each of the following changes is made, separately, to the experiment.

(i) The amplitude of the transmitted waves is doubled.

.....

.....

..... [2]

(ii) The separation between the transmitters is halved.

.....

.....

..... [2]

4 The graphs in Fig.4.1 show how the resistance of a metal resistor and a thermistor change when the temperature changes.

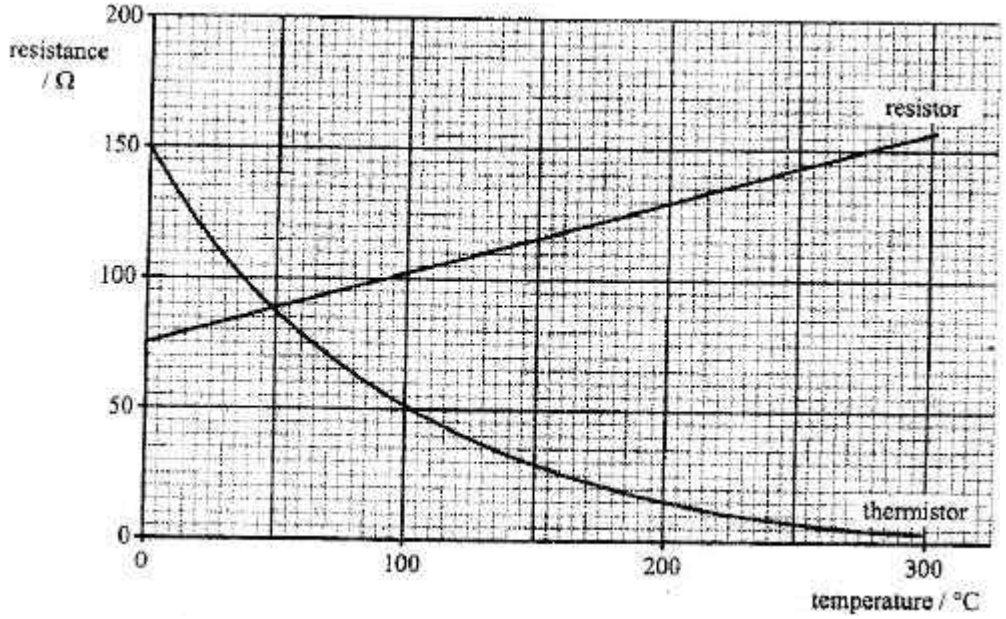

Fig. 4.1

(a) Explain why the resistance of the metal resistor increases when its temperature rises.

……

……

…… [2]

(b) At what temperature does the metal resistor have twice the resistance of the thermistor?

temperature = ……℃ [1]

(c) The metal resistor R and the thermistor T are connected in series as shown in Fig. 4.2 together with a battery of e.m.f. of 5.0 V, and are kept at the same temperature as each other.

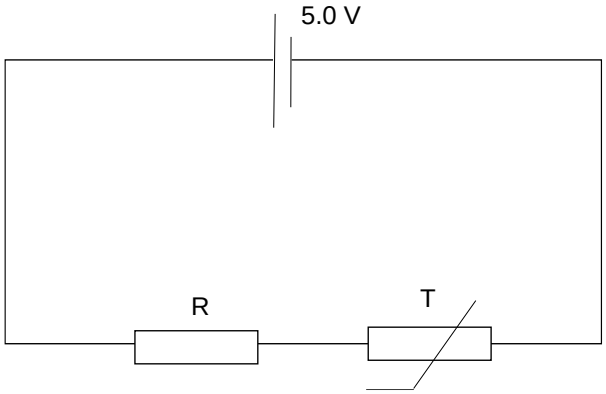

Fig. 4.2

(i) Explain what is meant by an e.m.f. of 5.0 V of a battery.

……

……

…… [1]

(ii) Calculate the potential difference across R when its resistance is twice that of T.

potential difference = ……V [1]

(iii) Determine the current in the circuit when their temperature is 150 ºC.

current = ……A [2]

(iv) Describe the effect on the current in the circuit as the temperature increases from zero to 100 °C.

……

……

…… [2]

5 **(a)** X-rays are produced when electrons are accelerated through a potential difference towards a metal target such as silver. Fig. 5.1 shows a typical X-ray intensity spectrum of silver (Ag) from an X-ray tube.

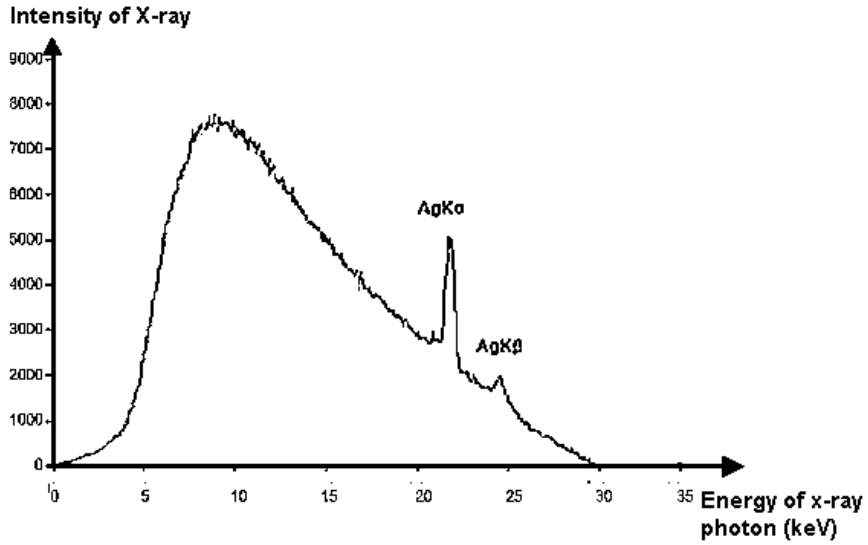

Fig. 5.1

(a) Explain how the characteristic lines of the X-ray spectrum are formed.

……

……

……

…… [2]

(b) Estimate the potential difference used to obtain the spectrum in Fig. 5.1.

potential difference = …… kV [1]

(c) Hence, determine the minimum wavelength of the photon in the X-ray spectrum.

minimum wavelength = ……m [2]

(d) Calculate the momentum of the photon calculated in part **(c)**.

momentum = …… kg m s^{-1} [2]

(d) On Fig. 5.1, sketch the expected graph when the potential difference used is 20 kV. [1]

Section B

Answer **two** questions in this section

6 **(a)** A load of mass *m* is suspended from the free end of a helical spring of spring constant *k*, as shown in Fig. 6.1.

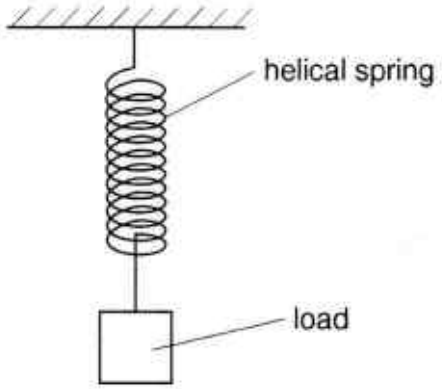

Fig. 6.1

Different masses of the same volume are suspended from the spring. The spring has an unextended length of 2.0 cm. The weight *W* of the mass and the length *L* of the spring are plotted in the Fig. 6.2.

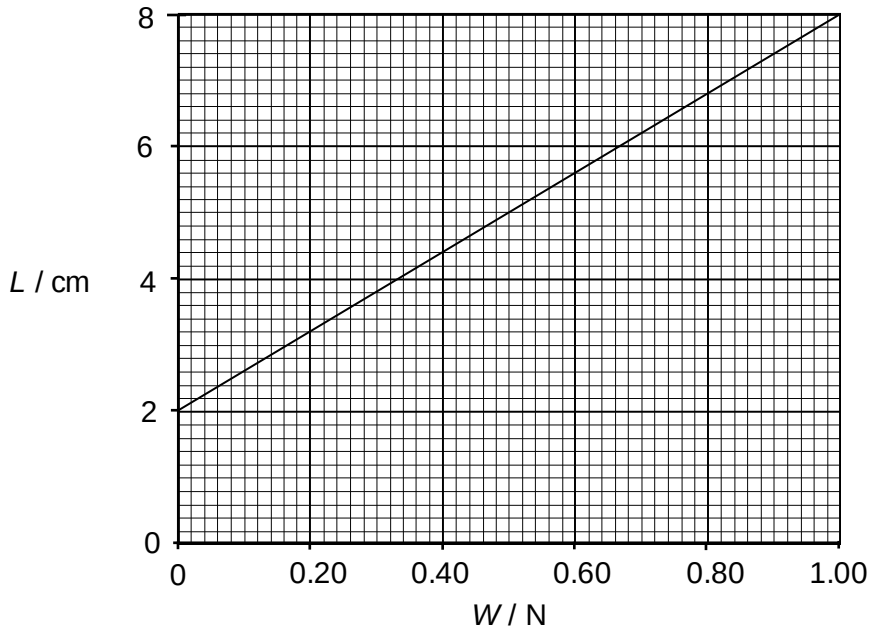

Fig. 6.2

(i) State and explain whether the spring obeys Hooke's Law.

……

……

……

[2]

(ii) On Fig. 6.2, shade the area of the graph that represents the additional energy stored in the spring when the weight on the spring is increased from 0.20 N to 0.60 N. [1]

(iii) Using Fig. 6.2, determine the spring constant *k*.

spring constant, *k* = ……N m^{-1} [2]

(b) When the load is displaced vertically and released, it oscillates up and down in simple harmonic motion.

Motion sensors are used to monitor the movement of the load, and the variation with time *t* of the position of the load is as shown in Fig. 6.3.

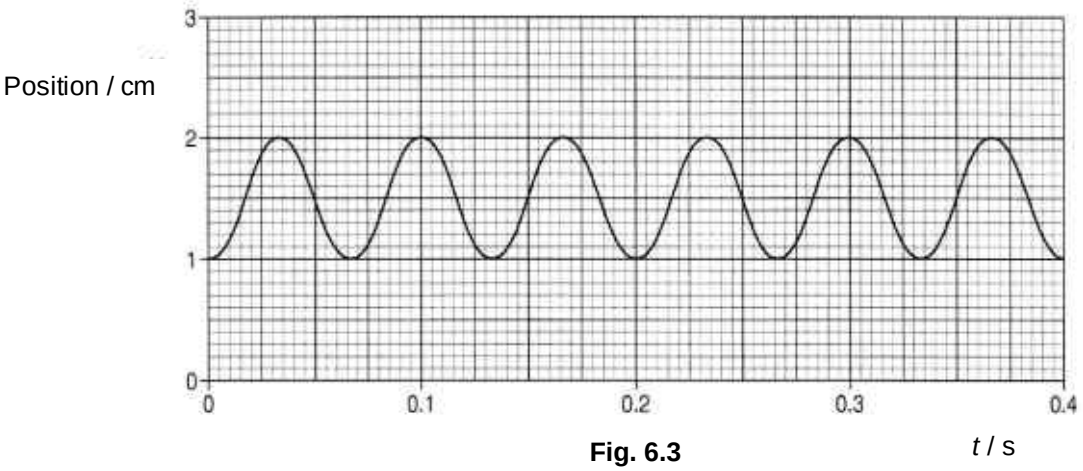

Fig. 6.3

(i) Define simple harmonic motion.

……

……

…… [2]

(ii) Suggest, with a reason, whether the motion in Fig. 6.3 is damped or undamped.

……

…… [1]

(iii) Determine the frequency f of the oscillation of the load.

f = …… Hz [1]

(iv) Show that the total energy E_T of the oscillations is given by

$$E_T = 2\pi^2 m f^2 a^2$$

where a is the amplitude of vibration of the load. [2]

(v) Given the mass of the load is 90g, use the expression in **(iv)** to calculate the total energy of the oscillations.

E_T = …… J [2]

(c) The load in Fig. 6.1 is now replaced by a long bar magnet and made to oscillate vertically such that one pole of the magnet oscillates within the coil as shown in Fig. 6.4.

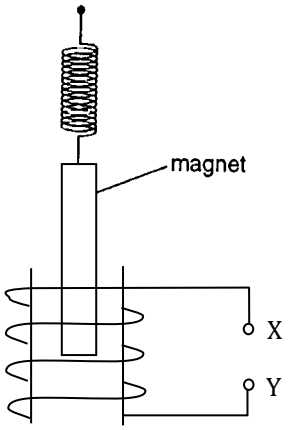

Fig 6.4

(i) The variation with time *t* of the position of the magnet is shown in Fig. 6.3. An oscilloscope with large resistance is connected across the terminals XY.

Sketch a labelled graph below to show how the voltage across XY varies with time, with the given starting position as shown on Fig. 6.3. [2]



Fig. 6.5

(ii) Using Faraday's Law to explain the variation of Fig. 6.5.

……

……

……

…… [3]

(iii) The experiment is repeated with all variables kept unchanged except for a resistor which is now connected in series with the coil as shown below.

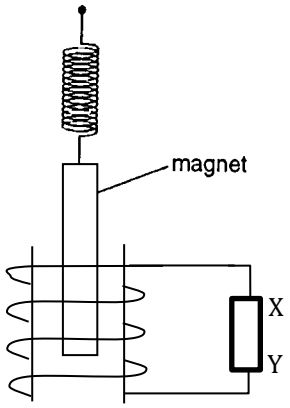

Fig. 6.5

Explain why the amplitude of the oscillating magnet gradually decreases.

……

……

…… [2]

7 **(a)** The first law of thermodynamics may be expressed in terms of the equation

$$\Delta U = q + w$$

(i) Identify each of the terms in this equation.

……

…… [1]

State and explain in molecular terms, what happens to the internal energy of a fixed mass of an ideal gas in the following process:

(ii) the volume is decreased at constant temperature,

……

……

……

…… [2]

(iii) the gas is compressed in a thermally-insulated container.

……

……

……

…… [2]

(b) A gas at a temperature of 20.0 °C and pressure of 1.01×10^5 Pa, occupies a volume of 1000 cm^3. The gas then undergoes a change.

The gas is supplied with 176 J of thermal energy and the gas expands at constant pressure to a volume of 1500 cm^3.

Calculate

(i) the final temperature of the gas,

final temperature = ... K [2]

(ii) the work done by the gas in expanding,

work done = ... J [1]

(iii) the number of moles of gas in the cylinder,

number of moles = ... [1]

,

(iv) the change in internal energy of the gas at the end of the change.

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

(c) Two small charged metal spheres A and B are situated in a vacuum. The distance between the centres of the spheres is 12.0 cm, as shown in Fig. 7.1.

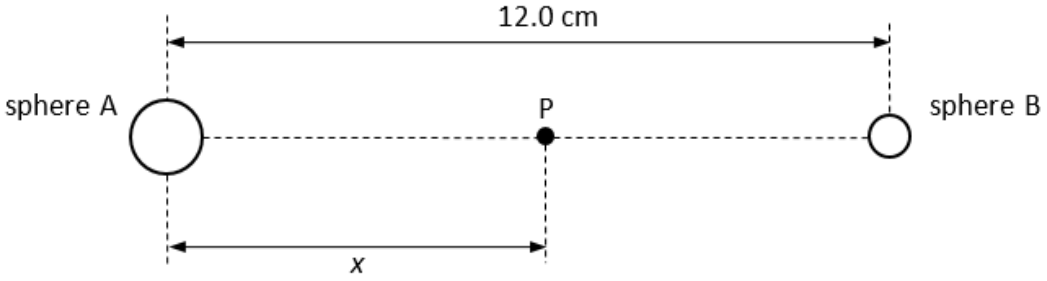

Fig. 7.1

The charge on each sphere may be assumed to be a point charge at the centre of the sphere. Point P is a movable point that lies on the line joining the centres of the spheres and is 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. 7.2.

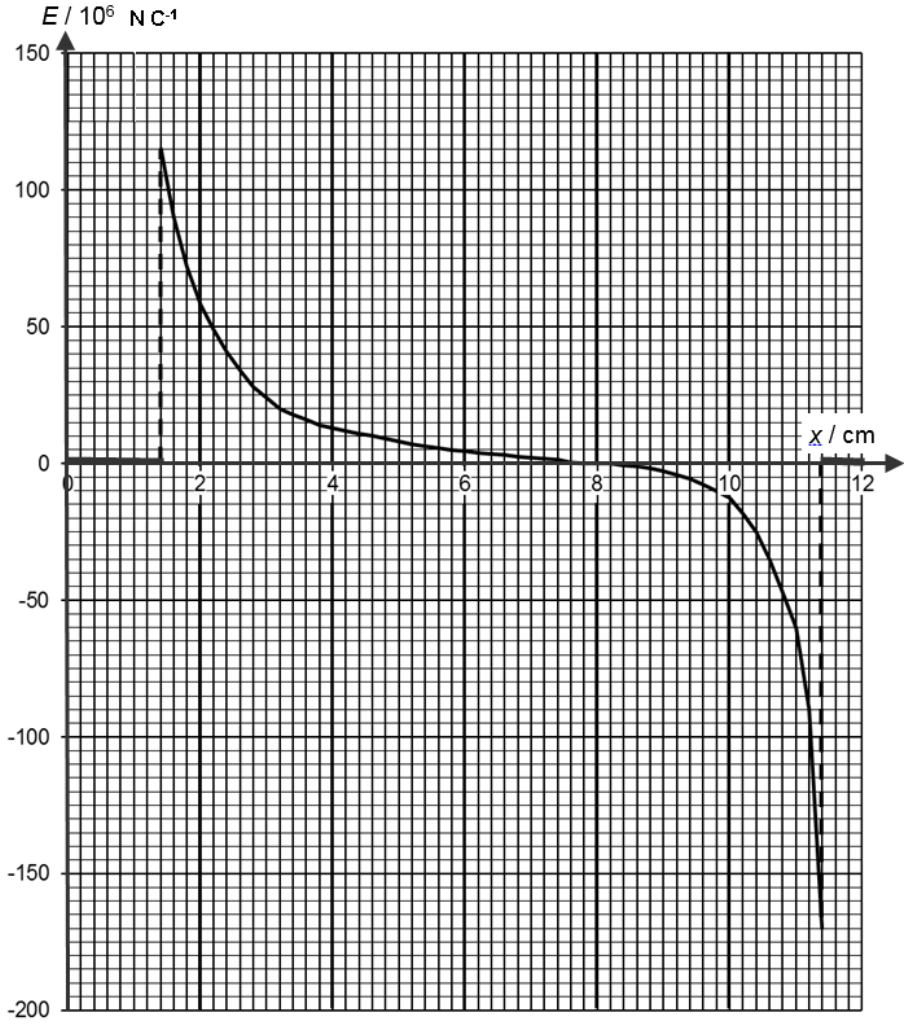

Fig. 7.2

(i) Comment, with explanation, on the polarity of the two charges.

.....

.....

.....

..... [2]

(ii) Use Fig. 7.2 to determine the ratio $\frac{\text{charge on sphere A}}{\text{charge on sphere B}}$.

ratio = ... [2]

(iii) Hence, on Fig. 7.3, sketch the electric field lines due to these two charges. [2]



Fig. 7.3

(iv) State the relation between electric field strength *E* and electric potential *V*.

..... [1]

(v) A negative point charge of −0.20 C is moved by an external force from the point where x = 2.0 cm to the point where x = 8.0 cm, along the line joining the centres of the spheres.

Use Fig. 7.2 to determine the magnitude of the net work done by the external force in this process.

net work done = ... J [2]

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8 (a) An unstable nucleus of mass number A disintegrates by the emission of an alpha particle as shown in Fig. 8.

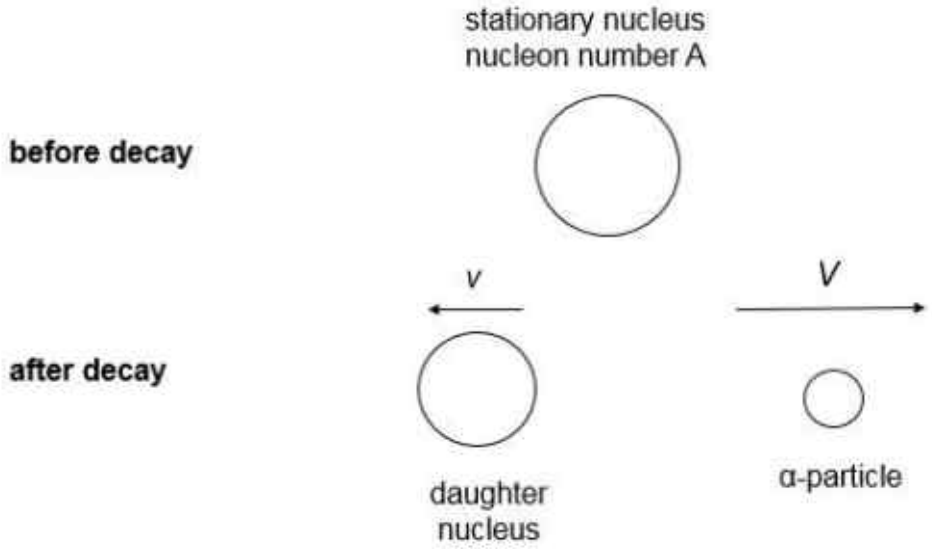


Fig. 8

The nucleus is stationary before the decay.
After the decay, the initial speed of the alpha particle is *V* and that of the daughter nucleus is *v*.

(i) the decay to a stable nucleus is both spontaneous and random. Explain what is meant by

1. spontaneous decay,

……

…… [1]

2. random decay.

……

…… [1]

(ii) Derive an expression, in terms of A, *V* and *v* to represent conservation of linear momentum for this decay.

…… [1]

(iii) Show that the ratio of the kinetic energy of the alpha particle to that of the daughter nucleus is given by the expression

$$\frac{KE_\alpha}{KE_D} = \frac{1}{4}(A-4).$$

[3]

(b) The element in **(a)** is radioactive isotope plutonium-238 ($^{238}_{94}Pu$) and the daughter nucleus is an isotope of uranium (U).

The mass of $^{238}_{94}Pu$ is 238.0496u and the mass of an alpha particle is 4.0096u.

Given that the total energy of the products is 5.649 MeV,

(i) calculate the mass of the uranium nucleus formed in the reaction, giving your answer in terms of atomic mass units to suitable significant figures.

mass of uranium nucleus = …….. u [2]

(ii) use your answer from **(a)(iii)** to show that the kinetic energy of the alpha particle is 5.55 MeV. [3]

(iii) In practice, the alpha particle is found to have an energy of 5.32 MeV, rather than 5.55 MeV, as calculated **(b)(ii)**.

Suggest

1. an explanation for the difference in energy,

……..

…….. [1]

2. why the uranium nucleus and alpha particle do not move off in opposite directions.

……

…… [1]

(c) The uranium-235 nucleus undergoes the fission reaction and produces strontium-90 and xenon-142 nuclei.

(i) Define *decay constant*.

……

…… [1]

(ii) The half-life of strontium-90 is 28.0 years. Calculate the decay constant of strontium-90.

decay constant = …….. s^{-1} [2]

(iii) The decay constant of xenon-142 is 0.462 s^{-1}. Initially, a sample of radioactive waste material contains equal numbers of strontium-90 and xenon-142 nuclei.

1. Use the values of the decay constants in **(c)(ii)** to calculate the time taken for the ratio $\frac{\text{number of strontium-90 nuclei}}{\text{number of xenon-142 nuclei}} = 1.20 \times 10^{6}$.

time = …… s [3]

2. Suggest why strontium-90 presents a greater problem than xenon-142 as radioactive waste in the long-term.

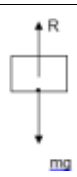
……..

…….. [1]

END OF PAPER

2016 MI PE2 H2 Physics Paper 1

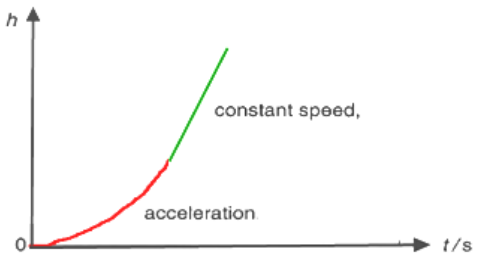
Qn	Ans	Discussions
1	B	Option A gives a radius of 6 cm; Option B gives a radius of 13 cm Option C gives a radius of 29 cm; Option D gives a radius of 62 cm So B is the most sensible answer
2	C	Let A = m ;Let B = It $\frac{\Delta Z}{Z} = \frac{\Delta m}{m} + \frac{\Delta I}{I} + \frac{\Delta t}{t}$ $\frac{\Delta Z}{Z} = \frac{0.02}{3.99} + \frac{0.05}{2.00} + \frac{1}{6000}$ = 0.029 %Z= 3.0%
3	A	Some KE lost due to completely inelastic collision. COM: 5.0 (200) = (95 + 5) v' v' = 10 m s^{-1} COE: Loss in KE = Gain in GPE ½ (95+5)(10)2 = (95+5) (9.81) h h = 5.1 m
4	C	$W_x = ma \rightarrow mgsin\theta = ma \rightarrow a = gsin\theta$ Acceleration is independent of mass.
5	D	0 – 2 s: constant negative velocity => displacement increases in negative direction, gradient of *s-t* graph constant and negative 2.0 - 2.8 s: decreasing negative velocity => displacement increases in negative direction, gradient of *s-t* graph deceasing to 0 2.8 - 4.0 s: increasing positive velocity => object changes direction to move towards origin, gradient of *s-t* graph increases from 0 to positive gradient 4 - 6 s: constant positive velocity => object moves towards origin and into the positive displacement region, Since the area above the graph is greater than the area under the graph; gradient of *s-t* graph is constant and positive
6	A	$v = u + at \quad = 9.81(2) = 19.62$ $v^2 = u^2 + 2as \quad 0 = 19.62^2 + 2a(0.025) \quad a = -7.7 \times 10^3$ m s^{-2}
7	C	The finger experienced upthrust due to the water when dipped into the water. By Newton's 3rd Law, there is a downward force exerted on water due to the finger. Therefore the new W increases. D is not the answer because the weight of the finger can only be experienced by the finger.
8	B	Rotational equilibrium: ACW moments = CW moments (2m)(Lsinθ) = (m)(½Lsin(90-θ)) tanθ = ¼ => θ = 14°
9	D	At the highest point, the object has minimum KE as V_y = 0, $V = V_x$ At the highest point, GPE is maximum as height is maximum At all time, total energy = KE + GPE (just for reference)
10	B	Power o/p = *F* x *v* = 2.0 x 20 x 10^{-2} = 0.40 W Power i/p = 100/20 x 0.40 = 2.0 W

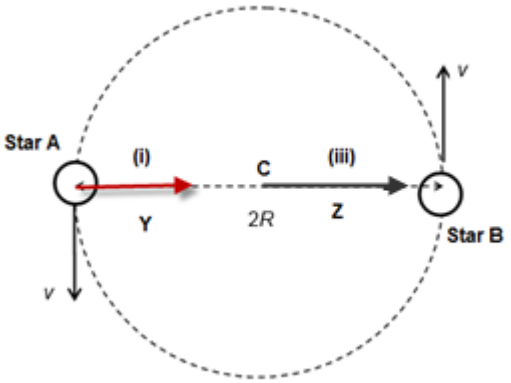
11	C	Net force acting on the satellite at that instant is now zero. Since the satellite is already moving with a speed tangent to the orbit. Newton's 1st law says that it will continue to move along the tangent to the orbit.
12	A	In a uniform circular motion, the magnitude of the tangential velocity and the radius of the object remain constant. Since $F_c = \frac{mv^2}{r}$,the centripetal force which is the resultant force of the stone must remain the same.
13	C	Potential is a scalar quantity. $\phi = -\frac{GM}{\left(\frac{d}{2}\right)} - \frac{GM}{\left(\frac{d}{2}\right)} = -\frac{4GM}{d}$
14	B	Using $T^2 \propto R^3$, $(\frac{27.3}{T})^2 = (\frac{R}{R/30})^3 \Rightarrow R = 0.166$ day ≈ 4.0 hour
15	B	 Net force: ma = mg – R Object will remain in contact when R is greater than 0. Object will lose contact when R = 0, Net force for shm: ma = mg For SHM, $a = \omega^2 x_o = (2\pi f)^2 x_o = g$ $x_o = \frac{g}{(2\pi f)^2} = \frac{9.81}{(2\pi(2.0))^2} = 0.062$ m
16	B	The degree of damping of Q is greater than that of P. Hence the resonant frequency of Q will be slightly lower and the amplitude of vibration at resonance will be lower compared to P.
17	B	Q = mcΔΘ= m(800)(100-20) = 64 000m for Q. The thermal energy required for solid Q to reach melting point is the lowest.
18	B	$\Delta U = \Delta Q + \Delta W = 80 + (-p\Delta V) = 80 - (1.0\text{x}10^5)(0.2 \text{ x } 10^{-3})$=+60 J
19	A	Angular frequency $\omega = \frac{2\pi}{T} = (0.02)^{-1}$ Thus $2\pi f = (0.02)^{-1}$ or $f = (2\pi \text{ x } 0.02)^{-1} = 7.96$ Hz. The speed of the wave, $v = f\lambda = 7.96 \text{ x } 6.28 = 50.0 \text{ m s}^{-1}$.
20	A	Use formula for diffraction grating: $d \sin\theta = n\lambda$ 1/d = 625 lines per mm = 625,000 lines per m, n = 1 $\theta = 20°$ $\lambda = 1/625{,}000 \text{ x } \sin 20° = 5.47 \text{ x } 10^{-7}$ m = 550 nm (2 s.f.)
21	B	On top of having two coherent sources, they must also have identical amplitudes to produce totally dark fringes when they interfere destructively. Not all coherent light sources produce light of equal amplitudes where they interfere destructively.

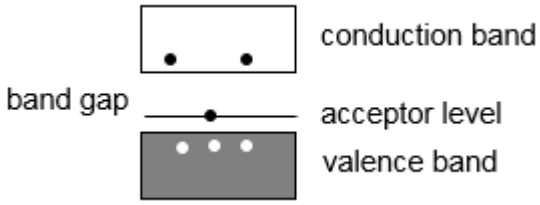
22	D	$I \propto A^2$ For maximum intensity, $I_o \propto (3A)^2$ For minimum intensity, $I \propto (A)^2$	$\frac{I}{I_o} = \left(\frac{A}{3A}\right)^2$ $I = \frac{I_o}{9}$
23	D	$F = Eq = (\frac{V}{d})q \Rightarrow d = \frac{Vq}{F} = \frac{2\times1.6\times10^{-19}}{6.4\times10^{-16}} = 0.0005m = 0.5mm$	
24	C	Electric field is a vector quantity. E-fields are directed away from the positive charges, hence the 4 E-field lines at X cancels vectorially. Resultant E-field at X is hence zero. Electric potential is a scalar quantity. Since all four charges are positive, the potentials at X due to all charges are positive and they add up numerically to produce a positive (non zero) potential at X.	
25	B	Does not obey Ohm's law as it is not a straight line passing through origin. When V > 1.8 V, its resistance is not constant.	
26	A	R=ρL/A: Original: R_1=ρ(4L)/A New: R_2=ρ(L)/4A R_1/R_2 =16:1	
27	C	When *R* decreases, the total resistance of the entire circuit decreases. As emf remains constant, the total current I_{total} increases. ($I_{total} = I_1 + I_2$) Because the current (I_{total}) flowing through R_1 increases, the p.d. across R_1 increases. This means that the p.d. across R_2 decreases, and that I_1 decreases. Since I_{total} increases and I_1 decreases, then I_2 must increase.	
28	B	When galvanometer reading is zero, V across XT = E_2 V per unit length of XY = (V across XT) / (length XT) = E_2 / (length XT)	
29	B	Applying the right-hand grip rule, the magnetic fields due to all 3 coils are out of the page in area Y. In X, 2 fields due to Coils 1 and 3 are into the page and 1 field due to Coil 2 is out of the page.	
30	A	Use Fleming Left Hand Rule to determine the charge of the particle. $\frac{mv^2}{r} = Bqv \rightarrow v \propto r$. Since r is decreasing, v is slowing down.	
31	B	$\varepsilon = -\frac{dNBA}{dt} = -NA\frac{dB}{dt}$ Max $-\frac{dB}{dt} = -0.2$ $\varepsilon = -(1)(0.2)(-0.2) = 0.04$ $\varepsilon = IR \rightarrow I = \frac{\varepsilon}{R} = \frac{0.04}{0.25} = 0.16A$	
32	C	KE electron E = ½ mv^2 = $p^2/2m$ De Broglie wavelength λ = h/p p = h/λ Thus E = $(h/\lambda)^2$ / 2m $\lambda^2 = (h^2/2m) / E$ Thus to obtain a straight line graph through the origin, one needs to plot a graph of λ against 1/√E.	

33	C	For unrectified circuit: $V_{rms} = \frac{V_o}{\sqrt{2}} = \frac{(2\text{ cm})(2\text{ V cm}^{-1})}{\sqrt{2}} = 2.828\text{ V}$ $\langle P \rangle = \frac{V_{rms}^2}{R} = \frac{2.828^2}{10} = 0.8\text{ W}$
34	B	$\frac{n_s}{n_p} = \frac{V_s}{V_p} = 2$
35	C	Photoelectric equation: $hf = \phi + E_k$, hf = 2.06 + 0.70 = 2.76 eV = 2.76 x 1.6 x 10^{-19} = 4.42 x 10^{-19} J
36	C	X to Z $\rightarrow E = h\frac{c}{\lambda} = 7.10 \times 10^{-19} J$ Y to Z $\rightarrow E = 9.95 \times 10^{-19} J$ X to Y $\rightarrow 9.95 \times 10^{-19} - 7.10 \times 10^{-19} = 2.85 \times 10^{-19} \rightarrow \lambda = 700nm$ Y must have higher energy than X and Z
37	A	Higher voltage means greater gain in kinetic energy for the electron and hence minimum wavelength will be smaller. Q has higher voltage. Spikes occur in same place, so same material.
38	A	At very low temperature, no external energy to create electron-hole pair.
39	C	Total binding energy for the two ^2_1H = 2 x 1.09 x 2 = 4.36 MeV. Total binding energy for ^3_2He = 3 x 2.54 = 7.62 MeV. Hence, the energy released = 7.62 - 4.36 = 3.26 MeV.
40	D	When the number of active nuclei in the two sources are equal, $N_1 = N_2$ $N = \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}} N_0$ $\left(\frac{1}{2}\right)^{\frac{t}{2}}(64) = \left(\frac{1}{2}\right)^{\frac{t}{3}}(8)$ $\left(\frac{1}{2}\right)^{\frac{t}{2}-\frac{t}{3}} = 2^{3-6}$ $\frac{t}{6} = 3$ $t = 18\text{ days}$

Millennia Institute Solutions for Prelim II Paper 2 2016

1(a)	The resultant force (acting in any direction) equals zero. The resultant moment <u>about any axis</u> (point) equals zero.	A1 A1
(b)(i)	Since the girl is in vertical equilibrium, $T_1 \sin 50^o + T_2 \sin 40^o = 392$ N Considering horizontal equilibrium, $T_1 \cos 50^o = T_2 \cos 40^o$ $T_1 = 300$ N $T_2 = 252$ N	M1 A1 A1
(ii)	$T_1 \sin\theta_1 + T_2 sin\theta_2 = mg$, if θ=0, there is no components of tensions to balance mg, Thus it is impossible to tighten the ropes until there is no sag.	B1 B1
(iii)	Method cannot be used as the girl is not in equilibrium (immediately after release). Upwards forces are larger than downwards forces / Resultant force is not zero / cannot form a closed triangle.	B1 B1
		9
2(a)	Using kinematics equation s= ut + ½ at^2 s = 0(3) + 1/2x0.5x(3^2) = 2.25 m	M1 A1
(b)	Change in height = 2.25 sin 40^0 =1.45 m Gain in GPE = mgh = 95 x 9.81 x1.45 = 1.351 kJ	M1 M1
(c)	 **acceleration stage [1] , constant speed stage [1]**	Label A1, A1
		6
3(a)	**Gravitational field strength** <u>at a point</u> in a gravitational field is defined as the <u>gravitational force per unit mass</u> acting on a body placed at that point.	B1

(b)(i)		A1
(ii)	Star A is moving in a circle and its direction is changing wrt time. According to N2L, a resultant force is required for the rate of change of momentum of star A. The direction of the resultant force is towards the centre of the circle; hence the direction of acceleration.	B1 B1
(iii)	See diagram – along line joining centres towards B	A1
(c)	gravitational field strength $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(4.22 \times 10^{7})^2}$ $g = 0.224$ N kg^{-1}	M1 A1
(d)	Both satellite and astronaut are falling freely with the same acceleration OR Contact force between satellite and astronaut is zero.	B1
		8
4(a)(i)	1. similarity: both have same amplitude/frequency/period 2. difference: phase difference of $\pi/2$ rad or movements is 90° out of phase	A1 A1
(ii)	$v = f\lambda$ Wavelength $\lambda = 0.8$ m $f = v/\lambda = 340/0.8 = 430$ Hz	M1 A1
(iii)	$I = k A^2$ $I_2 / I_1 = A_2^2 / A_1^2$ $I_R = (3/4)^2 \times 10 = 5.63$ W m^{-2}	M1 A1
(b)(i)	Microwaves are EM waves and it **does not require** a medium for propagation. Sound waves required a medium to propagate.	A1
(ii)	The transmitter emits microwaves that are plane <u>polarised vertically.</u> The detector can only detect microwaves that plane polarized horizontally when it is orientated horizontally. Hence the meter shows no reading.	B1 B1
		9
5(a)	Work done by e-field = gain in E_k of electron (COE) $q(\Delta V) = \frac{1}{2}mv^2 - 0$ $(2 \times 1.6 \times 10^{-19})(1.5 \times 10^{6}) = \frac{1}{2}(4 \times 1.66 \times 10^{-27})(v^2)$ $v = 1.2 \times 10^{7}$ m s^{-1}	M1 A1

(b)	The electric force on the alpha particles is constant in magnitude and direction throughout the motion and is perpedicular to the horizontal component of velocity. The electric force causes the alpha particles to travel with **uniform velocity** in the horizontal direction and **uniform acceleration** in the **vertical upward** direction. Hence the alpha particles follows a parabolic path.	B1 B1
(c)	$F_B = F_E \qquad Bqv = qE$ $B = \frac{E}{v} = \frac{3.8\times10^{6}}{1.2\times10^{7}} = 0.32\ \text{T}$ Magnetic field is directed <u>out of the plane of paper</u>.	M1 A1 A1
		7
6(a)(i)	Electromagnetic radiation is emitted when an electron falls from one discrete energy level to another energy level giving the photon a discrete amount of energy. Energy of photon is related to its wavelength.	B1
(ii)	$f = \frac{9.92\times10^{-19}}{6.63\times10^{-34}} = 1.5 \times 10^{15}$ Hz $\lambda = \frac{3\times10^{8}}{1.5\times10^{15}} = 2.0 \times 10^{-7}$ m	M1 A1
(b)	 Trivalent atoms results in empty acceptor levels to the energy band diagram, just above the valence band. Because the new levels are so near the valence band, at room temperature, valence electrons are raised into the new empty levels. Hence creating more holes in the valence band than electrons in conduction band that act as mobile charge carrier.	B1 B1 B1
		6

7 (a)

LED	V_0 / V	λ / nm	λ^{-1} / nm^{-1}
Infrared	0.866	1000	0.001000
Red	1.367	695	0.00144
Yellow	1.464	660	0.00152
Green	1.560	630	0.00159

A1

(b) 4 points plotted accurate to ½ square

A2

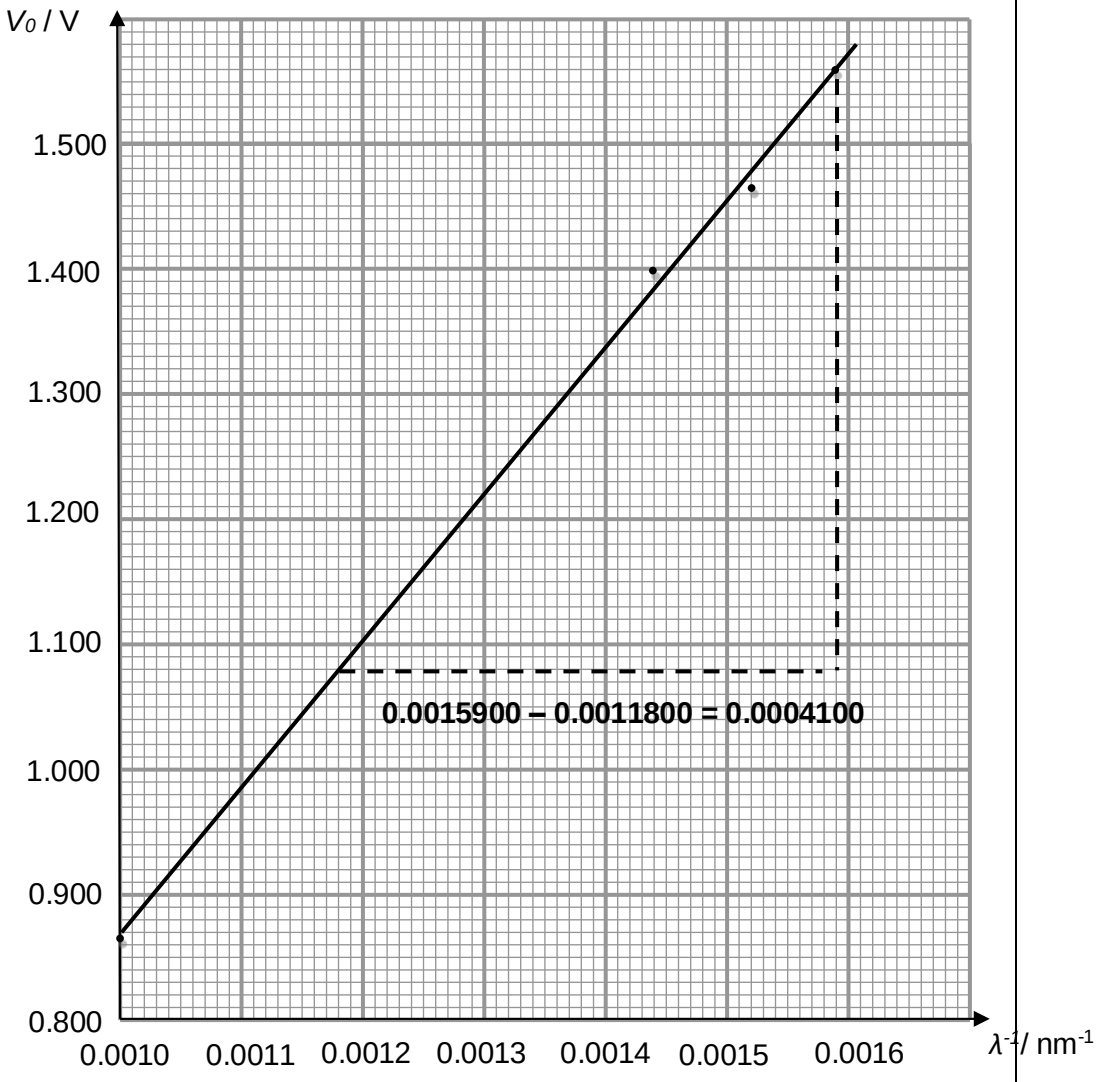


Fig. 7.3

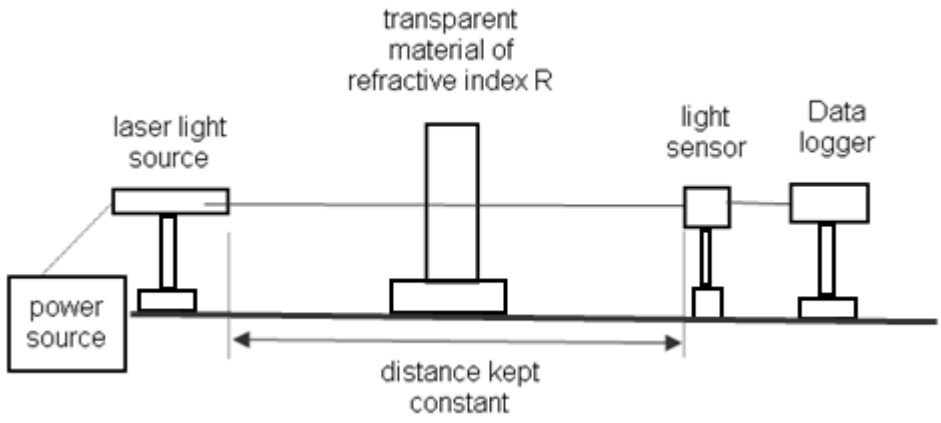
Best fit line

A1

(c) eV_0

A1

(d)	$E = \frac{hc}{\lambda}$ $\frac{hc}{\lambda} = eV_0$ $V_0 = \frac{hc}{e}(\frac{1}{\lambda})$ Hence, $\frac{hc}{e}$ is the gradient of the graph.	A1 A1
(e)	$\frac{hc}{e} = \frac{0.480}{0.0004100 \times 10^9}$ $h = \frac{0.480 \times 1.6 \times 10^{-19}}{0.0004100 \times 10^9 \times 3 \times 10^8}$ $= 6.24 \times 10^{-34}$	M1 M1 A1
(f)	The voltmeter may not be ideal hence V_0 is not accurate. It is difficult to determine exactly when the LED actually lit up hence it is difficult to determine V_0 exactly.	B1 B1
(g)	For a recombination to occur, the electrons de-excite from the conduction band to the valence band, thus emitting a photon corresponding to the energy gap. As E = hc/λ, the wavelength of the photons is of specific values.	B1 B1
(h)	Band gap = eV_0 = 0.866 x 1.6 x 10^{-19} = 1.39 x 10^{-19} J	 A1

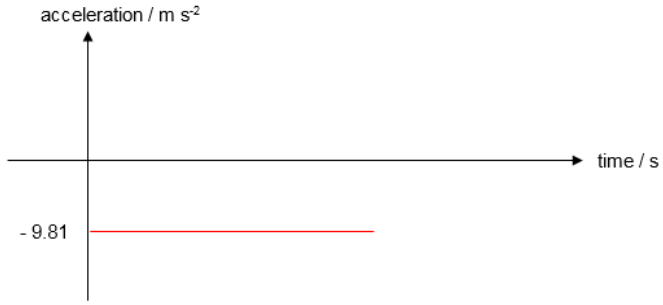
8	To investigate how the intensity of light depends on the refractive index of different type of transparent materials.	A1
	The refractive index of different type of transparent materials is the independent variable. The intensity of light after passing through the material is the dependent variable.	A1
	The control variables that need to be kept constant: 1. Meaure thickness of different transparent slides with a vernier or micrometer to ensure all same thickness. 2. The distance between the light source and the light sensor kept a fixed distance for fixed intensity. A meter rule is used to measure d the distance. 3. The angle between the laser and transparent slide is kept fixed by aligning along the same level. 4. The intensity light is kept constant using a constant power source.	A1 A1
	List a number of apparatus for the setup. Light sensor and datalogger; laser light and power supply; transparent slides, meter rule	
		A1
	Diagram must show with light source directed to light sensor. Transparent block.	
	<u>Procedure</u>: 1. Set up the apparatus as shown in the diagram above. 2. Use a metre rule to keep the distance d between the laser pointer and the light sensor constant. 3. Record the thickness of the transparent slide measured with a vernier calliper. 4. Switch on the laser so the beam is perpendicular to the transparent slide. This is checked using a set square. Use the same laser pointer through the experiment. 5. Record the intensity of light I that has fallen onto the light sensor connected to a datalogger. 6. Repeat steps 2 to 5 by using another transparent material with a different refractive index R but of the same thickness. 7. Record all data in a table.	A1 Control variable A1 IV & DV A1 Repeat steps

	Hypothesis: The relationship between intensity I and the refractive index of different transparent materials R is assumed to follow the equation : $I = k R^n$ where k and n are constant. Linearizing the equation to obtain a linear relationship between the variables. $\lg I = n \lg R + \lg k$. Analysis: 1. Calculate values of lg I and lg R. 2. Plot a graph of lg I against lg R. 3. If the trend of data points obtained fits a linear graph, the relationship $I = k R^n$ is valid. 4. Determine the gradient and the y-intercept of the straight line graph. 5. Calculate the values of k and n using the values of y-intercept and gradient respectively. <u>Accuracy</u>: 1. Wipe the glass clean with alcohol before each experiment to prevent any impurities or dust from affecting the accuracy of the results. 2. Carry the experiment in a dark room. This will minimise the amount of background light from affecting the accuracy of the results. 3. Attach a mirror to the slide to ensure laser beam is reflected back to the pointer. This will ensure slide is perpendicular to laser beam. <u>Safety Precaution</u>: 1. Wear laser safety goggles to prevent damage to the eye accidentally by the reflected laser beam. 2. Wear safety gloves to prevent cuts in case the microscope slides breaks.	A1 A1 A1 3 details required A1 2 details required

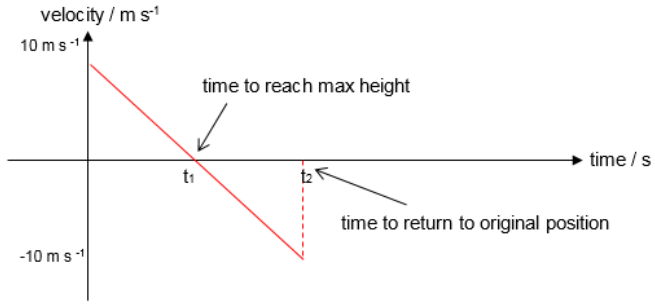
2016 MI PU3 H2 Physics Prelim 2 Paper 3 Answers

Section A

1 (a)

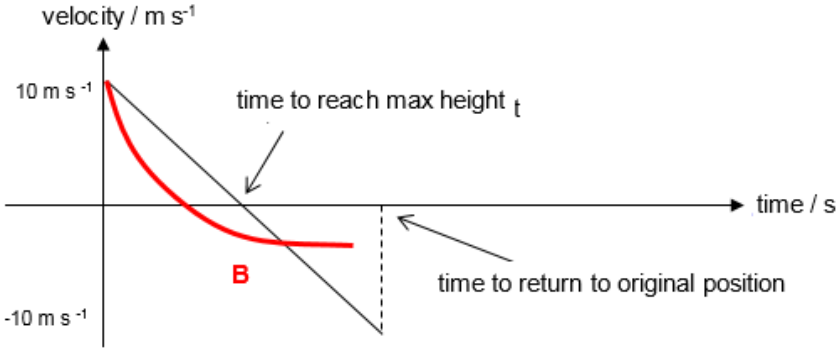


Sign convention: taking upwards as positive



Correct shape of a-t graph with correct sign based on given sign convention — A1
Correct labelling of times on v-t graph (equal time interval for negligible air resistance) — A1
Shape of v-t graph follow from a-t graph — A1
(Accept answers if student took downwards as positive)

(b)



Shape of graph: gradient of velocity steeper at start, then becomes gentler till v=0 gradient is parallel to original graph, then gradient continues to become gentler and less than 10 m s^{-1} — A1

Time taken to reach max height **shorter** than time to return to original position. — A1

(c) (i)

In the absence of air resistance, the **net force** on mass of water is gravitational force. — B1

The magnitude of acceration is 9.81 m s^{-2}. — B1

(ii)

Horizontal velocity: $V_x = 5 \cos 80^0 = 0.868$

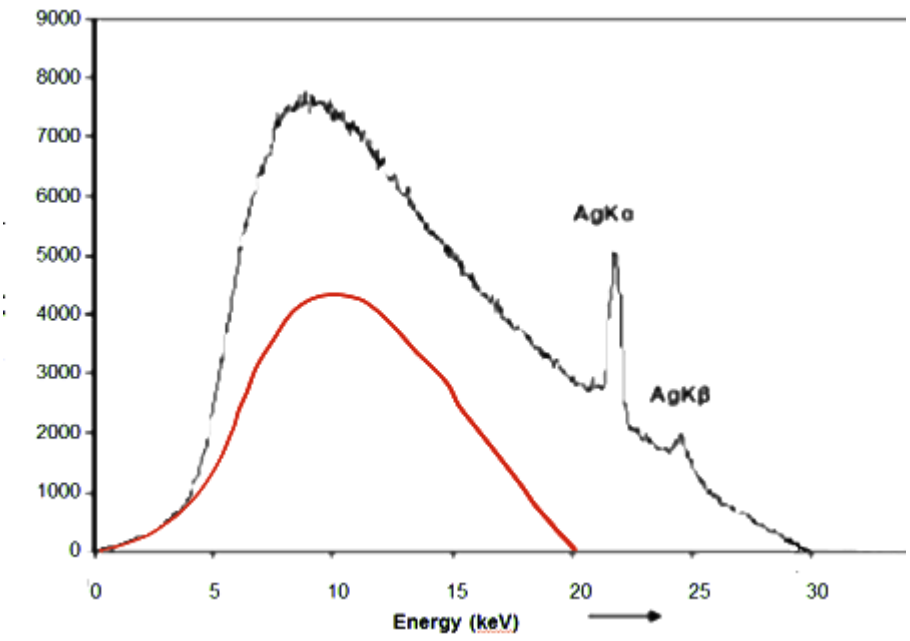
Vertical velocity : $(V_y)^2 = (5 \sin 80^0)^2 - 2\,(9.81)\,(-0.8)$ — M1

$v^2 = u^2 + 2as$ $\quad V_y = 6.33$

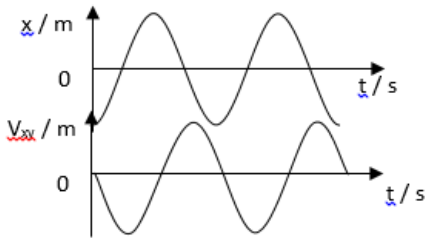
$\theta = \tan^{-1}(V_x / V_y)$ — B1

$= \tan^{-1}(0.868/6.33) = 7.8^0$

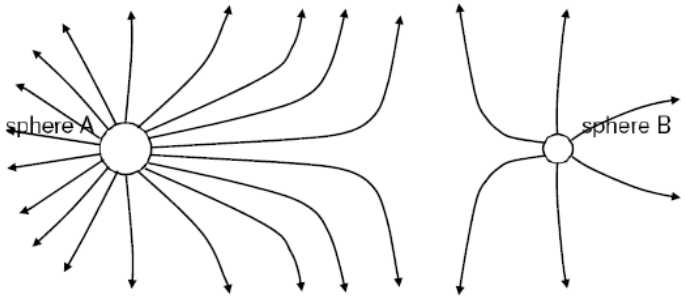
2	**(a)**	$\omega = \frac{\theta}{t}$ $\omega = \frac{2\pi x3}{90} = 0.209$		M1 A1
	(b)	Centripetal force F= mrω^2 F = 40 x 1.6 x 0.209^2 = 2.80 N ecf from (a)		M1 A1
	(c)	The velocity of Bucket 1 changes when its direction changes. According to Newtons's 2nd law the rate of change of momentum of the bucket required an external force to act on the bucket. Or Newton's 1st law, no resultant external force, no change in direction. Since velocity change due to direction, hence external force required.		B1 B1
	(d)	The centripetal force depends on the mass of the object (F= mrω^2) if r and ω are constant. Since the bucket 5 has less mass it will require less centripetal force compared to bucket 1.		B1 B1
3	**(a)**	Double slit seprartion: $x = \frac{\lambda D}{a} = \frac{0.030 \text{ x } 5}{0.20}$ = 0. 75 m		 M1 A1
	(b)	**(i)**	Intensity proportional to amplitude square I = k x^2 . Hence intensity increased by a factor of 4 Position is due to interference and is not affected. It depends on distance beween sources (or reference to double slit equation)	B1 B1
		(ii)	Intensity is dependent on the amplitude of wave. Hence intensity of maxima remains unchanged. Distance between maxima is double since it is inversely proportional to distance between sources. (Explaination for separation and intensity– look for evidence in b(i) or (ii) if not clearly stated.	B1 B1
4	**(a)**	As the temperature rises, the vibration of the crystal lattice structure increases. The increase in the amplitude of the vibration of the lattice structure increase the frequency of collisions with electrons. Hence reducing the flow of the electrons in the resistor and current is reduced. Thus the resistance of the metal resistor increases. (R=V/I)		B1 B1
	(b)	From the graph, temperature is 100 °C.		A1
	(c)	**(i)**	5.0 J of energy is converted from non-electrical to electrical form when a unit charge is driven through the source round a complete circuit.	B1
		(ii)	When the resistance of R is twice that of T, $V_R = \frac{2R}{2R+R} \times 5$ = 3.33 V	A1
		(iii)	When the temperature of 150 °C, $R_T = 30\Omega$ & $R_R = 115\Omega$ $5 = I(30 + 115) \quad I = 0.0345\, A$	M1 A1
		(iv)	When the temperature increases from zero to 100 °C, from the graph, the sum of the two components' resistance in the circuit decreases. For a constant e.m.f., since the total resistance in the circuit decreases, the current in the circuit increases.	B1 B1

5	**(a)**	The accelerated electrons knock out/eject electrons out of one of the innermost shells of the target atom, leaving a vacancy/hole. An electron from a higher energy shell falls to fill the vacancy, hence emitting an x-ray photon of <u>specific</u> energy/frequency/wavelength. Since energy of photon is specific, it gives rise to the characteristic line.	B1 B1
	(b)	potential difference = 30 kV	A1
	(c)	Minimum wavelength of the photon of the X-ray spectrum. $E = \frac{hc}{\lambda}$, $\lambda_{min} = \frac{hc}{E_{max}}$ E_{max} = 30 x 10^{3} x 1.6 x 10^{-19}= 4.807 x 10^{-15} J [Ecf from (b)] minimum wavelength = λ_{min} = 4.13 x 10^{-11} m	M1 A1
	(d)	momentum of the photon in part **(c)**. $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{4.13 \times 10^{-11}}$ momentum = p = 1.60 x 10^{-23} kg m s^{-1} [Ecf from (c))	M1 A1
	(e)	expected graph when the potential difference used is 20 kV  	A1

Section B

6	**(a)**	**(i)**	The spring obeys Hooke's law. Hooke's Law states that the extension x of a spring is directly proportional to the applied force F. The graph is L vs W, which is a linear graph. When W=0, extension = 0.	B1 B1
		(ii)	Correct shaded trapezium with a=0.20 N and b=0.60 N	A1
		(iii)	F = kx k = F / x = (0.80 – 0.20) / (4.8 – 1.2)x10^{-2} = 16.7 N m^{-1}	M1 A1
	(b)	**(i)**	Simple harmonic motion is defined as periodic motion in which acceleration (a) is proportional to, but oppositely directed to, the displacement (x) from its equilibrium position.	B1 B1
		(ii)	The motion is undamped as the amplitude of the oscillation remains constant over the period of time.	B1
		(iii)	Period = 0.2 / 3 = 0.0667 s Frequency = 1/T = 15 s^{-1}	 A1
		(iv)	Total energy = $\frac{1}{2}mv_{max}^2 = \frac{1}{2}m\omega^2 x_0^2$ $= \frac{1}{2}m(2\pi f)^2 a^2$ $= 2m\pi^2 f^2 a^2$ (shown)	B1 B1
		(v)	$E_T = 2\pi^2 m f^2 a^2$ $= 2\pi^2(0.090)(15)^2(0.5\times10^{-2})^2$ = 1.00 x 10^{-2} J	 M1 A1
	(c)	**(i)**	 Sinusoidal curve (pattern of V vs t) Indication of period = 0.0667 s	B1 B1
		(ii)	According to Faraday's law, the induced EMF is proportional to the rate of change of magnetic flux linkage, which is determined by the speed of the magnet. At the amplitude positions, the speed of the magnet is zero, which means the rate of change of flux linkage is zero, causing the induced EMF to be zero; at its equilibrium position, its speed is highest, which means the rate of change of flux linkage is highest, thus induced EMF is largest.	B1 B1 B1
		(iii)	When a resistor is connected, an induced current flows in the coil, generating an magnetic field in the coil which produces a magnetic force that opposes the motion of the magnet. **Or**: When a resistor is connected, an induced current flows in the coil, which dissipates energy in the resistor as heat. Thus the amplitude of the magnet's motion reduces with time. **Note**: When terminals X and Y are connected to a CRO / voltmeter, there is an induced EMF but **no induced current**, as the CRO / voltmeter has "infinite" resistance. Thus there is **no opposing B-field and no damping**.	B1 B1

7	**(a)**	**(i)**	ΔU is the increase in internal energy of system q is the thermal energy/heat supplied to system w is the work done on system	B1
		(ii)	At constant temperature, the random kinetic energy of the gas molecules remains unchanged. The internal energy of the gas **which is the sum of the random kinetic energy of its molecules** remains unchanged.	B1 B1
		(iii)	The work done on (compressing) the ideal gas increases the random kinetic energy of its molecules as PE between molecules do not exist. The internal energy of the gas increases.	B1 B1
	(b)	**(i)**	Using $pV = nRT$ Since pressure is constant, V is proportional to T for a fixed mass of gas. $V_1 / V_2 = T_1 / T_2$ $T_2 = (1500/1000) \times (273.15 + 20) = 440$ K	M1 C1
		(ii)	Work done by gas $W = p \times \Delta V$ $= 1.01 \times 10^5 \times (0.0015 - 0.0010) = 51$ J	 C1
		(iii)	No. of moles n= PV/RT n= $1.01 \times 10^5 \times 0.0010 / 8.31 \times 293.15 = 0.0415$ moles	 A1
		(iv)	By the first law of thermodynamics, the change in internal energy in Stage I is given by $\Delta U = Q + W$ $= +176 + (-51) = +125$ J	M1 A1
	(c)	**(i)**	The charges on the spheres are both positive because the field strength is zero at a point between the spheres or the electric fields are in opposite directions.	B1 B1
		(ii)	At x = 0.08 m, the electric field strength due to sphere A cancels out the electric field strength due to sphere B. Electric field strength due to sphere A: $E_A = \frac{Q_A}{4\pi\varepsilon_o x^2}$ --- (1) Electric field strength due to sphere B: $E_B = \frac{Q_B}{4\pi\varepsilon_o (0.12 - x)^2}$ --- (2) *Net field is zero :* $E_A = E_B$ $\frac{Q_A}{4\pi\varepsilon_o x^2} = \frac{Q_B}{4\pi\varepsilon_o (0.12 - x)^2}$ $\frac{Q_A}{4\pi\varepsilon_o (0.08)^2} = \frac{Q_B}{4\pi\varepsilon_o (0.04)^2}$ $\frac{Q_A}{Q_B} = \left(\frac{0.08}{0.04}\right)^2 = 4$ Allow estimation from graph, 7.8 cm < x < 8.2 cm	M1 C1

		(iii)	Diagram  Deduct 1 mark if any of the following is not shown. • Correct field line direction and shape. • At least more field lines radiating out of sphere A than sphere B. • Location of neutral point nearer to sphere B.	A1 A1
		(iv)	The field strength is negative of the potential gradient, i.e. $E = -\frac{dV}{dx}$ (not $\frac{V}{x}$).	B1
		(v)	$V = -\int_{x=2cm}^{x=8cm} E\,dx$ Hence, change in potential from x = 2.0 cm to x = 8.0 cm, ΔV = area under E−x graph (from x = 2.0 cm to x = 8.0 cm) Counting the number of squares, estimated about 3 (1 cm $\times$ 25 $\times$ 10^6 N C^{-1}) squares or 75 (2 mm $\times$ 5 $\times$ 10^6 N C^{-1}) squares $\Delta V = 3\times(0.01\times 25\times 10^6) = 7.5\times 10^5$ V (accept any logical estimation of area under E−x graph) Magnitude of W.D. by external force, W = $q \times \Delta V$ W.D. = 0.20 $\times$ 7.5 x 10^5 = 1.5 $\times$ 10^5 J (accept ± 10 % deviation)	M1 C1

8	**(a)**	**(i)**	**1.**	Spontaneous decay means that the decay occurs without external stimuli and its rate does not depend on physical conditions like temperature, pressure or chemical reactions.	B1
			2.	Random decay means that it is impossible to state exactly which nucleus or when a particular nucleus will disintegrate, but only the probability of decay in unit time interval for a particular radioactive isotope.	B1
		(ii)	0 = - (A-4)V + 4v		A1
		(iii)	From (ii), V = $\frac{1}{4}(A-4)$v $\frac{KE_\alpha}{KE_D} = \frac{\frac{1}{2}(4u)V^2}{\frac{1}{2}(A-4)uv^2}$ $= \frac{\frac{1}{2}(4u)\frac{1}{4}^2\ (A-4)^2v^2}{\frac{1}{2}(A-4)uv^2} = \frac{1}{4}(A-4)$		M1 M1 M1
	(b)	**(i)**	By using the conservation of mass-energy, $(m_{Pu} - m_U - m_\alpha)\ \ c^2 = kinetic\ energy$ $(238.0496 - m_U - 4.0096)\ \ (3\times10^8)^2 = 5.649\times10^6\times1.6\times10^{-19}$ m_u=234.0400u		M1 A1
		(ii)	$\frac{KE_\alpha}{KE_D} = \frac{1}{4}(A-4)$ $KE_\alpha = \frac{1}{4}(A-4)KE_D = \frac{1}{4}(238-4)KE_D = 58.5KE_D$ $KE_D = 0.01709KE_\alpha$ $KE_\alpha + KE_D = KE_{Total}$ $KE_\alpha + 0.01709KE_\alpha = 5.649$ $KE_\alpha = 5.55\ MeV$		M1 M1 M1
		(iii)	**1.**	The energy released is not purely in the form of kinetic energy of the uranium nucleus and alpha particle. Some energy is released as γ radiation.	B1
			2.	According to de Broglie's equation $p = \frac{h}{\lambda}$, the γ photon has a small but non-zero momentum. The γ photon will move off in a direction that is **<u>not collinear</u>** with the uranium nucleus and alpha particle. This produces a vertical component of momentum of the γ photon that is perpendicular to v and V. For momentum to be conserved, the total momentum must be conserved, including in the vertical component. Hence, the uranium nucleus and alpha particle cannot move in opposite directions.	B1
	(c)	**(i)**	Decay constant of a radioactive nuclide is the probability of radioactive decay per unit time		B1
		(ii)	$\lambda = \frac{\ln 2}{(28\times365\times24\times3600)}$ $= 7.85\times10^{-10}\ s^{-1}$		M1 A1

		(iii)	*1.*	$\frac{N_0 \exp(-7.85\times10^{10}t)}{N_0 \exp(-0.462t)} = 1.2 \times 10^6$; $\exp(0.462t) = 1.2 \times 10^6$ $t = 30.3$ s	M1 M1 A1
			2.	Activity of the strontium will be much greater than that of the xenon (from part iii.1.) and extent of health hazard depends on activity. **OR** Much longer half-life, and since A = λN, there will be storage problems.	B1

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/01

Paper 1 Multiple Choice **22 September 2016**

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

	Class	Reg No
Candidate Name:		

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

In the Index Number section, shade your index number using the first two spaces (e.g. index number 5 should be entered as "05"). Ignore the remaining numbers and letters.

There are **forty** 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 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.

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	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm \omega\sqrt{x_o^{\,2} - x^2}$
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	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 The SI unit for magnetic flux density is the tesla (T). How should the tesla be expressed in terms of SI base units?

A $\text{kg s}^{-1}\text{ A}^{-2}$ **B** $\text{kg s}^{-2}\text{ A}^{-1}$ **C** $\text{kg s}^{-1}\text{ C}^{-1}$ **D** $\text{kg s}^{-2}\text{ C}^{2}$

2 Which pair includes a vector and scalar quantity?

A	displacement	acceleration
B	magnetic flux density	kinetic energy
C	power	electromotive force
D	electric current	potential energy

3 A stone falls freely from rest to the ground. The effect of air resistance on the stone is negligible. The stone travels $\frac{3}{4}$ of the total distance to the ground in the last two seconds of its fall. What is the total time of its fall?

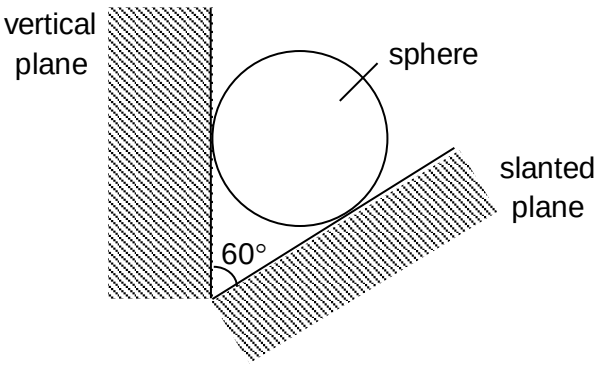
A 1.3 s **B** 2.7 s **C** 4.0 s **D** 14.9 s

4 A man throws a stone upwards off the edge of a cliff with an initial velocity u. The stone reaches the highest point at 2.0 s and then reaches the bottom of the cliff at 7.0 s. Air resistance is negligible.

Which of the following shows the correct signs for displacement s, velocity v and acceleration a of the stone at the respective times t?

	t / s	s	v	a
A	1.0	+	+	+
B	3.0	+	+	−
C	3.5	−	−	−
D	6.5	−	−	−

5 A uniform sphere of weight 15 N is placed in between two smooth planes as shown.



What is the magnitude of the force exerted by the vertical plane on the sphere?

A zero **B** 7.5 N **C** 8.7 N **D** 13.0 N

6 A mass is suspended using a spring balance from the ceiling of a lift.

When the lift is moving up at a constant speed, the reading on the spring balance is F. Under which of the following situations is the reading on the spring balance more than F?

A The lift is moving down at increasing speed

B The lift is moving down at decreasing speed

C The lift is moving down at constant speed

D The lift is stationary

7 A particle X moving with kinetic energy E and momentum p makes a head-on inelastic collision with an identical particle Y which is initially at rest.

Which of the following options shows possible values for the kinetic energy of the particle X and the system as a whole, and the magnitude of the momentum of X and the system as a whole, after this collision?

	kinetic energy of		momentum of	
	X	system	X	system
A	0	E	0	p
B	$\frac{E}{2}$	E	$\frac{p}{2}$	p
C	$\frac{E}{4}$	$\frac{E}{2}$	$\frac{p}{4}$	$\frac{p}{2}$
D	$\frac{E}{4}$	$\frac{E}{2}$	$\frac{p}{2}$	p

8 Two ice boats, of masses m and $2m$, are made to compete in a race on a frictionless frozen lake. The boats have identical sails so that the wind pushes them forward with the same force. The two boats start from rest and travel the same distance.

Which of the following statements is correct?

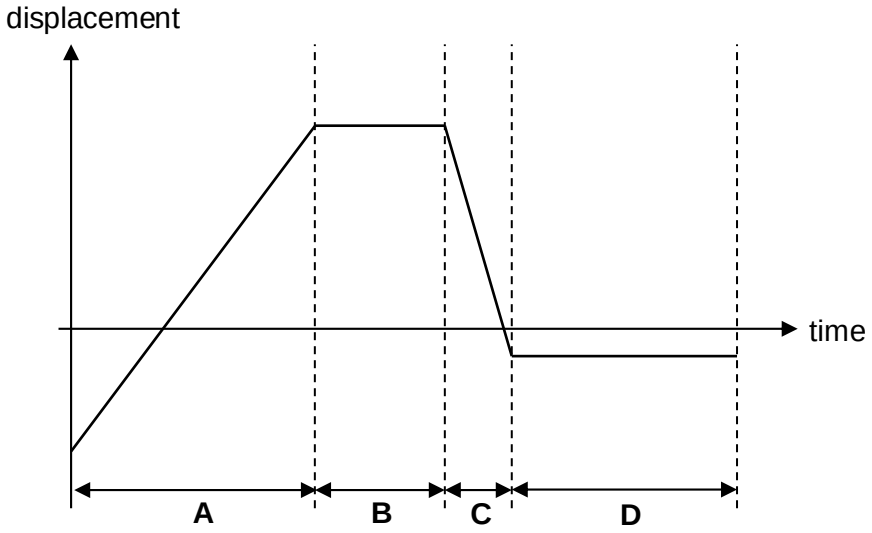
A The boat of mass m will win the race but the two boats will have the same final speed.

B The boat of mass m will win the race but it will have a lower final kinetic energy.

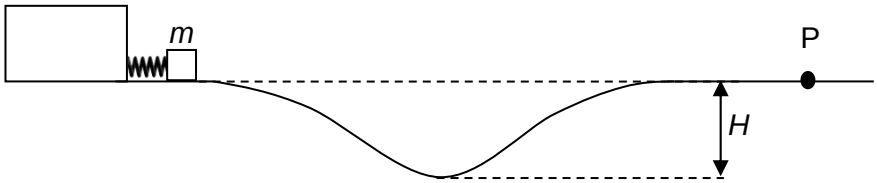
C The boat of mass m will win the race and it will have a higher final kinetic energy.

D The boat of mass m will win the race but the two boats will have the same final kinetic energy.

9 The following shows a displacement-time graph of a mass being moved on a table. It experiences a constant force of friction. Which time interval has the greatest work done per unit time against friction?



10 A small mass *m* is launched by a spring and travels along a rough track to a point P. The spring constant is *k* and the initial compression of the spring was *x*. As it travels to P it goes through a dip of depth *H*. The mass experiences a constant force of friction *f* for the entire distance of *d*.



What is the kinetic energy of the mass at point P?

A $\frac{1}{2}kx^2 - fd$

B $\frac{1}{2}kx^2 + fd + mgH$

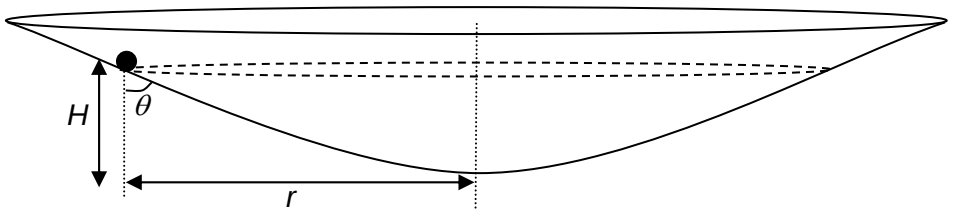
C $\frac{1}{2}kx^2 + fd$

D $\frac{1}{2}kx^2 - fd - mgH$

11 An object of mass *m* moves in a complete circle with constant speed *v*. What is the average momentum of the object?

A zero **B** $\frac{1}{2}mv$ **C** mv **D** $2mv$

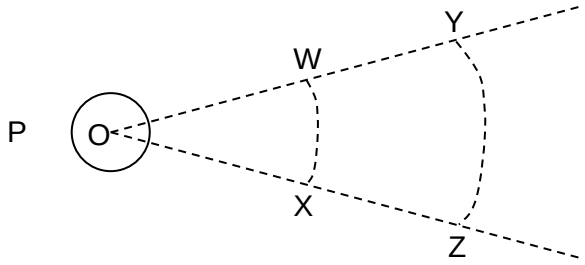
12 A sphere of mass *m* moves along a smooth horizontal circular path of radius *r* in a bowl with a constant linear speed *v*.



Which of the following gives the expression for angle θ?

A $\tan^{-1}\left(\frac{v^2}{rg}\right)$ **B** $\tan^{-1}\left(\frac{rg}{v^2}\right)$ **C** $\tan^{-1}\left(\frac{r}{H}\right)$ **D** $\tan^{-1}\left(\frac{H}{r}\right)$

13 P is a planet with centre O. WX and YZ are equipotential lines. Which one of the following is false?



A $\frac{\text{Gravitational potential at W}}{\text{Gravitational potential at Y}} = \frac{\text{Distance OY}}{\text{Distance OW}}$

B $\frac{\text{Kinetic energy of satellite orbiting at radius OW}}{\text{Kinetic energy of the same satellite orbiting at radius OY}} = \frac{\text{Distance OY}}{\text{Distance OW}}$

C Positive work has to be done by an external agent to move a mass from Y to W.

D The work needed to move a mass from W to Z is equal to the work needed to move a mass from W to Y.

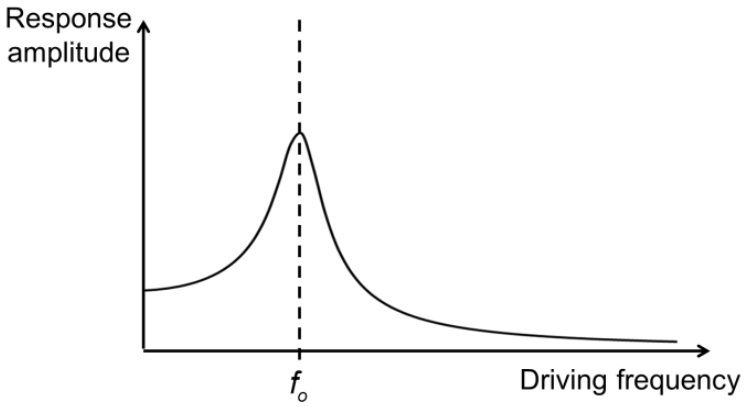
14 A satellite is in a circular orbit about Earth. Its orbital radius is about 30 times the diameter of the Earth. Taking the gravitational field strength on the Earth's surface to be 10 N kg^{-1}, what is the value of the Earth's gravitational field strength experienced by the satellite?

A 2.8 mN kg^{-1} **B** 11 mN kg^{-1} **C** 40 mN kg^{-1} **D** 100 mN kg^{-1}

15 An object is moving in simple harmonic motion. The amplitude of its motion is 0.050 m and its frequency is 2.0 Hz. It starts from the amplitude at $t = 0$ s. What is the magnitude of the acceleration of the object at 1.7 s?

A 0.25 m s^{-2} **B** 0.51 m s^{-2} **C** 1.60 m s^{-2} **D** 6.40 m s^{-2}

16 The figure shows how the response amplitude of a lightly-damped oscillating system varies with the frequency at which it is driven. The resonance peak occurs at a driving frequency of f_0.



When damping is increased, which of the following is false?

A The resonant frequency decreases.

B The amplitude of the oscillation decreases.

C The sharpness of the resonance peak decreases.

D The period of the oscillation at resonance decreases.

17 At a pressure of about 610 Pa, water, water vapour and ice can co-exist in equilibrium at a temperature of 0.01 °C. This is known as the triple point of water. Which statement about the properties of the molecules at this temperature is true?

A Molecules in ice are closer to one another than molecules in liquid water.

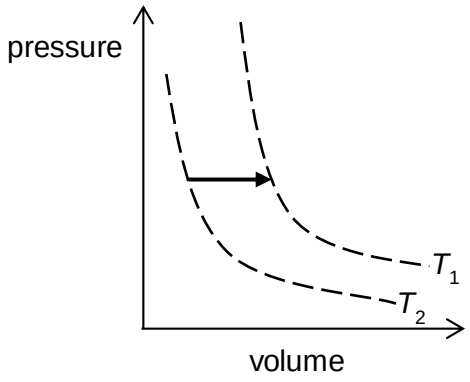
B Molecules in water vapour have a larger mean kinetic energy than molecules in liquid water.

C Molecules in water vapour are less massive than molecules in liquid water.

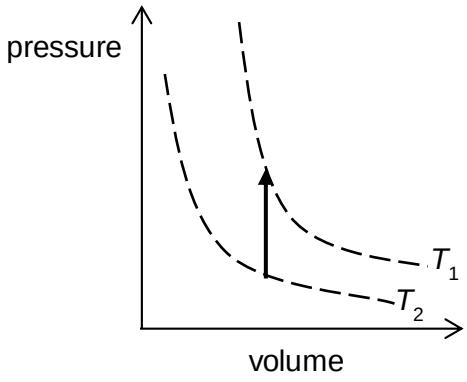
D Molecules in water vapour have the same r.m.s. speed as molecules in liquid water.

18 A closed system of an ideal gas can undergo different thermodynamic processes. Which of the following arrows shows a process that can occur without any heat exchange between the system and its environment?

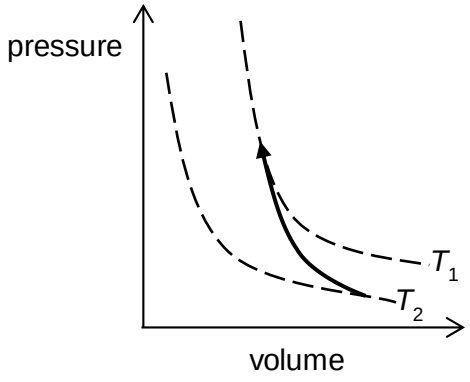
A



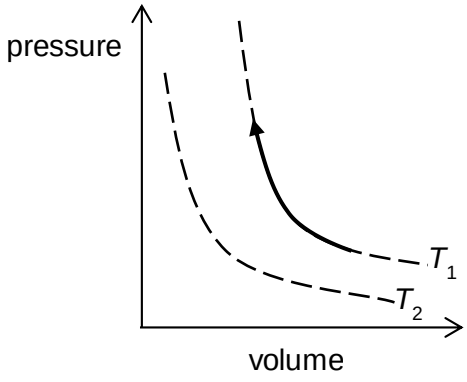
B



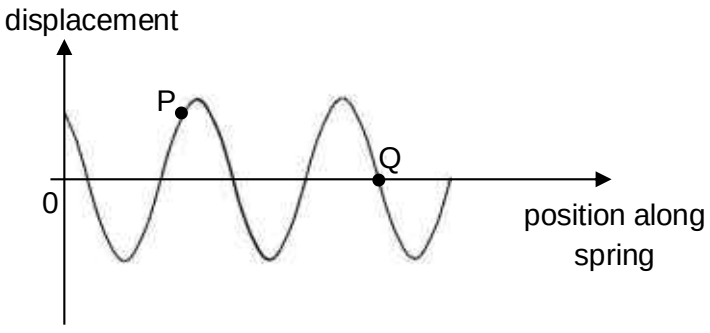
C



D



19 A longitudinal wave travels to the right along a long horizontal spring. The graph below shows the displacement of different points of the spring at a given instant of time.



Which of the following statements is true?

A P is moving vertically downwards.

B P and Q are moving in opposite directions.

C Q is stationary.

D P has higher speed than Q.

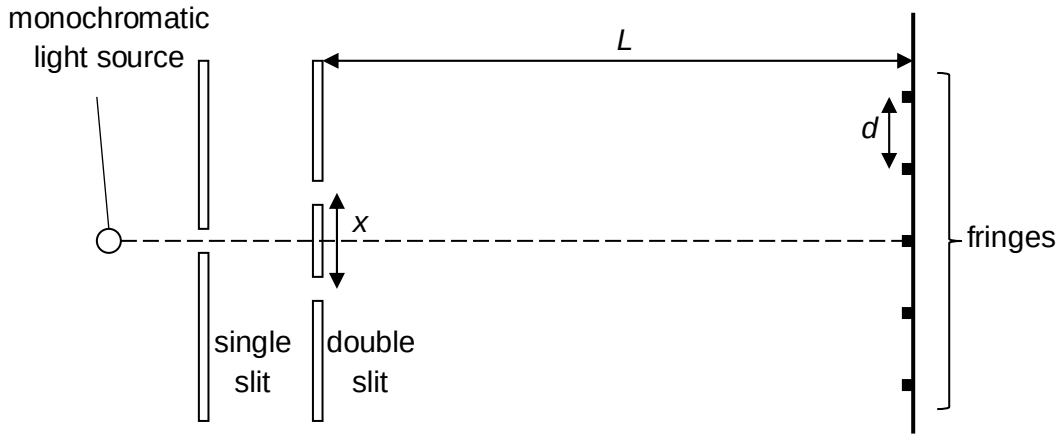
20 Two speakers S_1 and S_2 emit coherent sound waves. The sound waves reach a point P by two paths which differ in length by 0.70 m. When the frequency of the sound is gradually increased, the resultant intensity at P goes through a series of maxima and minima.

A maximum occurs when the frequency is 2400 Hz and the next maximum occurs at 2800 Hz.

What is the speed of the sound waves?

A 200 m s^{-1} **B** 280 m s^{-1} **C** 340 m s^{-1} **D** 400 m s^{-1}

21 A double slit experiment is shown below. The light source has wavelength λ, the slit separation is x, the fringe separation is d and the distance between the slits and screen is L.



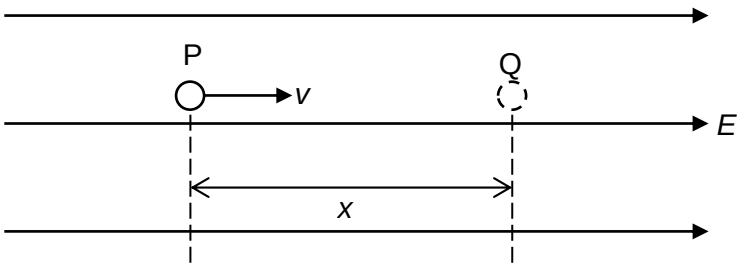
The wavelength is increased to 2λ, the slit separation is increased to $4x$ and the distance between the slits and the screen is decreased to $\frac{1}{2}L$. What is the resulting fringe separation?

A 0.25 d **B** 0.50 d **C** 2.0 d **D** 4.0 d

22 A diffraction grating has 500 lines per millimeter and is illuminated normally by monochromatic light of wavelength 600 nm. What is the total number of bright fringes seen on the screen?

A 3 **B** 4 **C** 6 **D** 7

23 An electron with charge e and mass m travels from point P to point Q within a uniform electric field of strength E. At point P, the electron has a velocity of v. It comes to a stop at point Q.

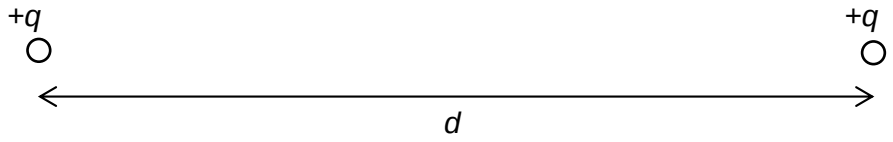


The distance between point P and Q is x. Which expression gives the value of x?

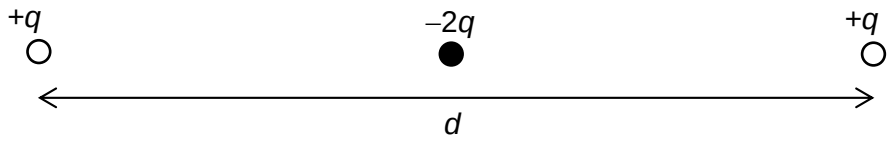
A $\frac{mv}{E}$ **B** $\frac{mv}{Ee}$ **C** $\frac{mv^2}{2E}$ **D** $\frac{mv^2}{2Ee}$

[Turn over

24 A system of two fixed point charges of $+q$ are at a distance d apart. The electric potential energy of the system is U.



Another point charge of $-2q$ is brought from infinity to the mid-point between the positive point charges as shown below.



What is the electric potential energy of the new system?

A zero **B** $-3\,U$ **C** $-7\,U$ **D** $-8\,U$

25 A cell of e.m.f. E and internal resistance r is connected to a variable resistor R as shown in Fig. (a).

Fig. (b) shows the variation with ammeter reading I of the voltmeter reading V as R is varied.

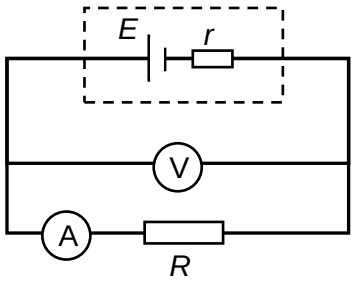


Fig. (a)

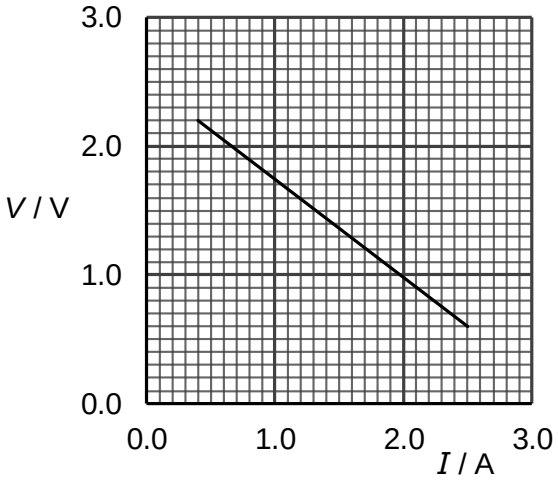
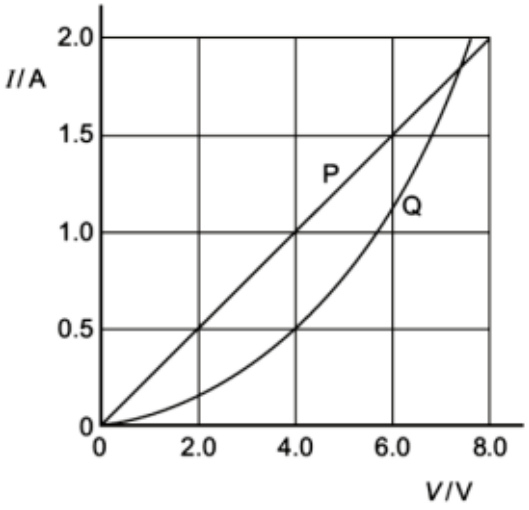


Fig. (b)

What is the e.m.f. and internal resistance of the battery?

	E / V	r / Ω
A	2.2	1.3
B	2.5	1.3
C	2.2	0.76
D	2.5	0.76

26 The *I*-*V* characteristics of two electrical components P and Q are shown below.



Which of the following statements is false?

A Q could be a thermistor.

B The resistance of Q decreases as current increases.

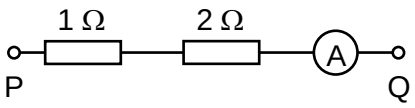
C When the current is 1.9 A, the resistance of Q is approximately half that of P.

D When the current is 0.5 A, the power dissipated in Q is double that in P.

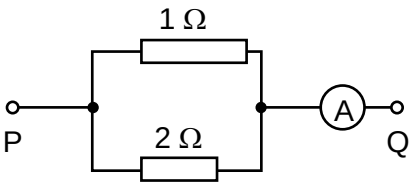
27 An ammeter with a resistance of 2 Ω is placed in different resistor configurations.

The same potential difference is applied across P and Q. In which configuration does the ammeter give the smallest reading?

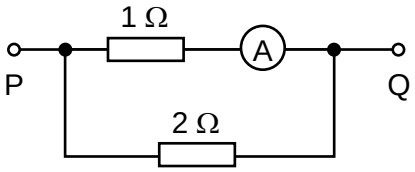
A



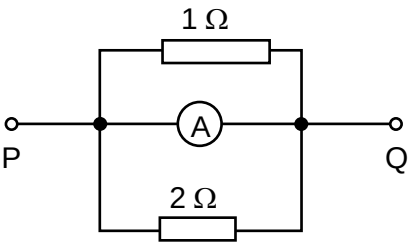
B



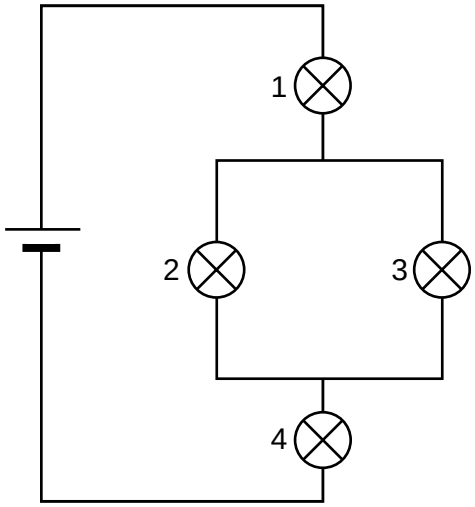
C



D



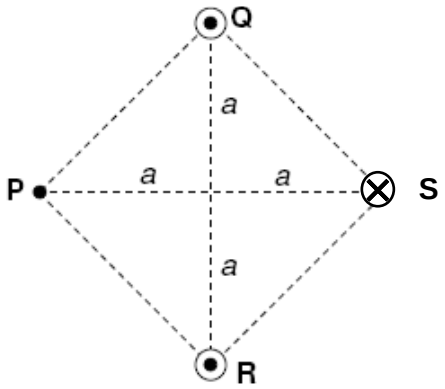
28 An ideal cell and four identical bulbs are connected as shown.



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	brighter	dimmer	dimmer

29 Three long, parallel conductors, Q, R and S carry currents of equal magnitude. The figure below shows the plan view of the conductors, whereby the current in S is opposite in direction to those in Q and R. The distance between P and S is 2*a*.



Which of the following shows the direction of the magnetic field at point P?

A zero field **B** ↓ **C** ↑ **D** →

30 Fig. (a) shows a square coil CDEF of sides 0.25 m, lying in a vertical plane and carrying a current I of 2.0 A. The magnetic flux density B of 0.010 T is parallel to DE.

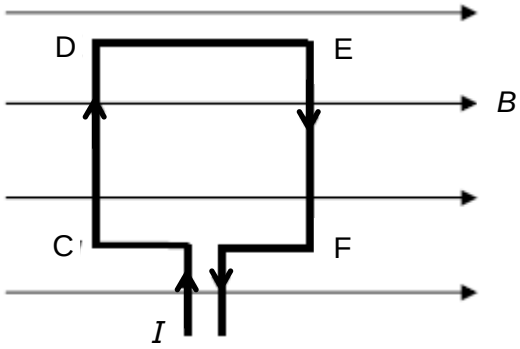


Fig. (a) side view

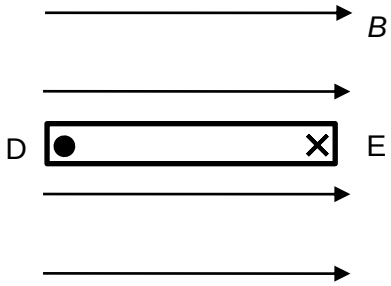


Fig. (b) top view

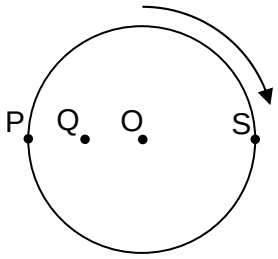
What is the magnitude of the torque and its direction when viewed from the top, as shown in Fig. (b)?

A 1.3×10^{-3} Nm, clockwise
B 1.3×10^{-3} Nm, anticlockwise
C 2.5×10^{-3} Nm, clockwise
D 2.5×10^{-3} Nm, anticlockwise

31 A magnetic field passes through a coil perpendicularly. The magnetic flux density changes from 0.60 T to 0.80 T at a constant rate over a duration of 0.50 s. The magnitude of the induced e.m.f. in the coil is 13 V. What could possibly be the number of turns of the coil and the area of the coil?

	number of turns of coil	area of coil / m^2
A	50	0.65
B	20	0.54
C	10	0.81
D	5	1.0

32 An uniform aluminium disc is rotated about its centre O at a constant angular speed. It is placed in a magnetic field perpendicular to its surface. P and S are on the circumference, and Q is midway between O and P. The magnitude of the e.m.f. between any two points "X" and "Y" is denoted as E_{XY}.



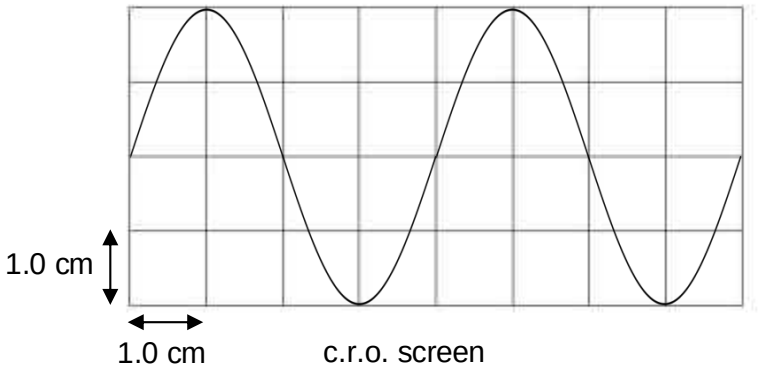
Which of the following options is correct?

A	$E_{PQ} < E_{QS}$	$E_{PQ} = E_{QO}$
B	$E_{PQ} < E_{QS}$	$E_{PQ} > E_{QO}$
C	$E_{PQ} = E_{QS}$	$E_{PQ} = E_{QO}$
D	$E_{PQ} = E_{QS}$	$E_{PQ} > E_{QO}$

33 The primary coil of an ideal transformer has a sinusoidal alternating current. The phase difference between the alternating currents of the primary coil and secondary coil is

A zero **B** $\frac{\pi}{4}$ rad **C** $\frac{\pi}{2}$ rad **D** π rad

34 A cathode-ray oscilloscope (c.r.o) screen with a grid of 1 cm squares displays an alternating voltage waveform. The settings of the oscilloscope are: gain = 5.00 V cm^{-1}, time base = 2.0 s cm^{-1}.



Which expression gives the e.m.f. of this waveform?

A 2.0 sin 4.0 t **B** 5.0 sin 2.0 t

C 10 sin 0.785 t **D** 10 sin 3.1 t

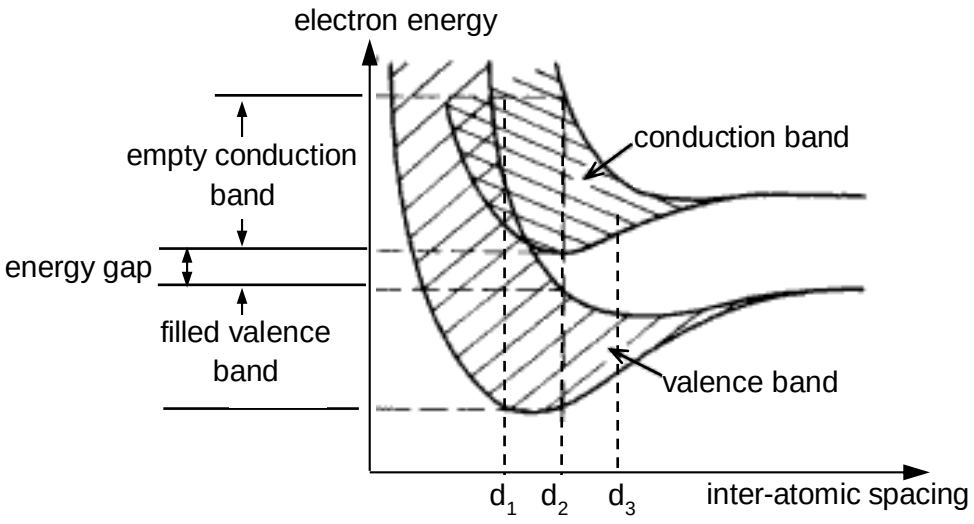
35 The equation $hf = \phi + \frac{1}{2}mv_{max}^2$ is used when studying the photoelectric effect. What is the meaning of each term in this equation?

	hf	ϕ	$\frac{1}{2}mv_{max}^2$
A	the energy of an incoming photon	the least energy required to release an electron	the maximum kinetic energy of a photoelectron
B	the energy of an incoming photoelectron	the work done by the incoming photoelectron	the maximum kinetic energy of the outgoing photoelectron
C	the energy of an incoming photoelectron	the least energy required to release an photon	the maximum kinetic energy of a photon
D	the energy of an incoming photon	the work done by the incoming photon	the maximum kinetic energy of the outgoing photon

36 What is a reasonable estimate, to one significant figure, of the energy of a photon of red light?

A 2 eV **B** 3 eV **C** 4 eV **D** 5 eV

37 The figure below shows how the energy of electrons in the conduction and valence bands varies with inter-atomic spacing. d_1, d_2 and d_3 are the equilibrium inter-atomic separations for different solids of varying electrical properties.



Which correctly lists the type of materials with their corresponding inter-atomic spacing?

	d_1	d_2	d_3
A	conductor	insulator	semiconductor
B	conductor	semiconductor	insulator
C	insulator	semiconductor	conductor
D	semiconductor	conductor	insulator

[Turn over

38 Which of the following statements about lasers is false?

A Population inversion is needed for continued lasing to occur.

B Laser beams are highly coherent and always monochromatic.

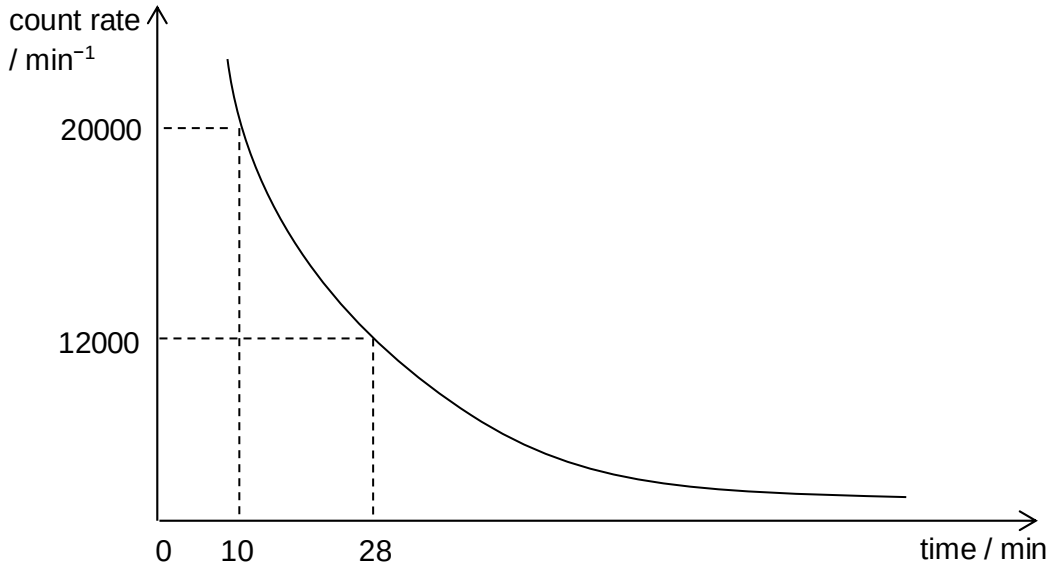
C It is possible to produce laser beams that are perfectly collimated (do not spread).

D The atoms in a laser system must have a meta-stable state for lasing to occur.

39 The mass defect of ${}^{P}_{Q}X$ is Δm. What is the binding energy per nucleon of X?

A $\frac{\Delta m}{Q}$ **B** $\frac{\Delta m}{P}$ **C** $\frac{c^2 \Delta m}{Q}$ **D** $\frac{c^2 \Delta m}{P}$

40 The figure shows the variation with time of the count rate for a sample of a radioactive isotope.



What is the half-life of the isotope?

A 18 min **B** 20 min **C** 24 min **D** 32 min

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/02

Paper 2 Structured Questions **16 September 2016**

1 hour 45 minutes

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

Candidate Name: _____ Class _____ Reg No _____

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 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.

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	/ 10
3	/ 8
4	/ 12
5	/ 11
6	/ 9
7	/ 12
Deductions	
Total	/ 72

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	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm \omega\sqrt{x_o^{\,2} - x^2}$
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	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** An object S of weight 10.0 N is supported by two ropes A and B, as shown in Fig. 1.1.

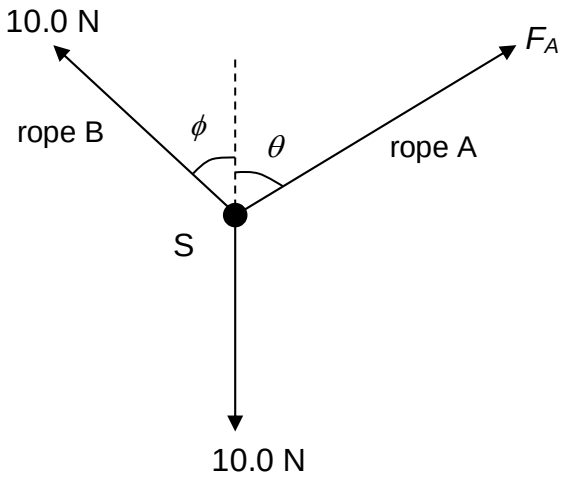


Fig. 1.1

Rope A is at an angle θ to the vertical and exerts force F_A on S. Rope B is at an angle ϕ to the vertical and exerts a force of 10.0 N on S.

The angle ϕ of rope B is varied from 0° to 90°. The force F_A is varied in magnitude and direction to keep S in equilibrium.

(i) Determine the magnitude and direction of force F_A when the angle ϕ is 30°.

magnitude of F_A = ...N

angle θ = ...° [3]

(ii) Explain, without detailed calculation, why the magnitude of F_A increases as the angle ϕ is increased from 0° to 90°.

.....

.....

.....

.....

.....

..... [3]

(b) Cart A, moving rightward at a speed of 10 m s^{-1}, collided head-on with an identical cart B, which was initially stationary. During the collision, 20% of the kinetic energy was dissipated. Determine the magnitude and direction of the velocity of cart A after the collision.

magnitude of velocity of cart A = ... m s^{-1}

direction of velocity of cart A = ... [4]

2 **(a)** A pendulum bob undergoes simple harmonic motion.

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

.....

..... [1]

(ii) Fig. 2.1 shows the variation with time of the displacement of the bob.

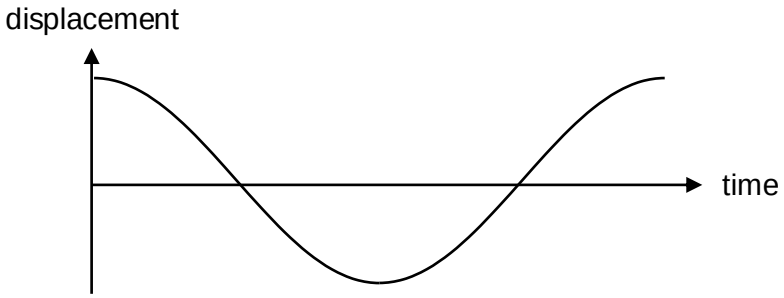


Fig. 2.1

On Fig. 2.1,

1. Label with 'A' the point(s) at which the magnitude of acceleration of the pendulum bob is a maximum. [1]

2. Label with 'S' the point(s) at which the speed of the pendulum bob is a maximum. [1]

(b) Fig. 2.2 shows a pendulum bob of mass 60 g. It is displaced until its centre is 3.5 cm above its rest position and then released from rest. The length of the pendulum is 160 cm.

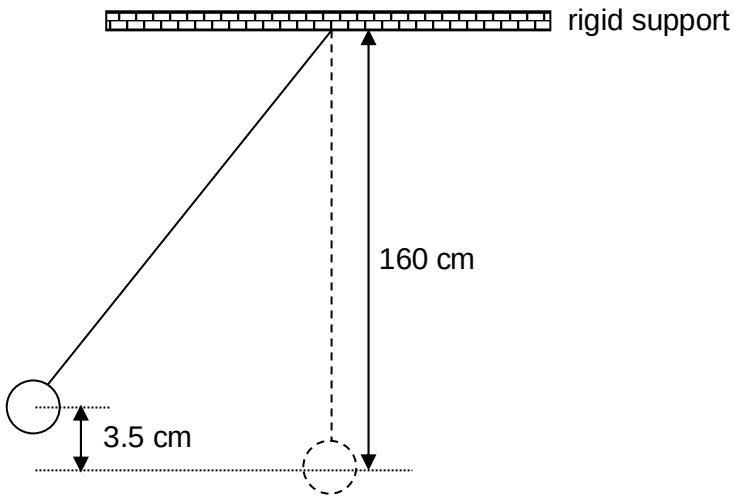


Fig. 2.2

(i) Calculate the speed of the pendulum bob at the midpoint of the oscillation.

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

(ii) Calculate the magnitude of the tension in the string when the pendulum bob is at the midpoint of the oscillation.

tension = ... N [2]

(c) An obstacle of length 60 cm is now placed directly beneath the point of suspension, so that only the lower section (100 cm) of the string can follow the pendulum bob when it swings to the right, as shown in Fig. 2.3.

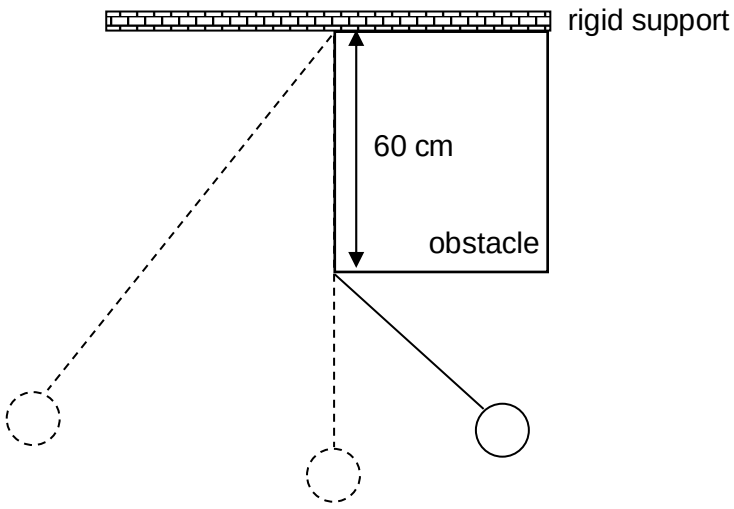


Fig. 2.3

The period of the pendulum is given by the expression

$$T = 2\pi\sqrt{\frac{L}{g}},$$

where L is the length of the pendulum and g the acceleration of free fall.

Calculate the period for the setup in Fig. 2.3.

period = ...s [3]

3 **(a)** Define electric field strength at a point.

.....

..... [1]

(b) Two point charges A and B are fixed at a distance of 6.0 cm apart, as shown in Fig. 3.1.

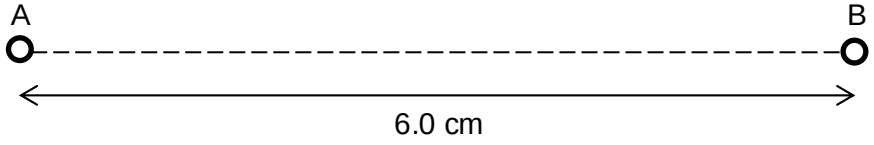


Fig. 3.1

The variation with distance *d* from A of the net electric field strength *E* along the line AB is shown in Fig. 3.2.

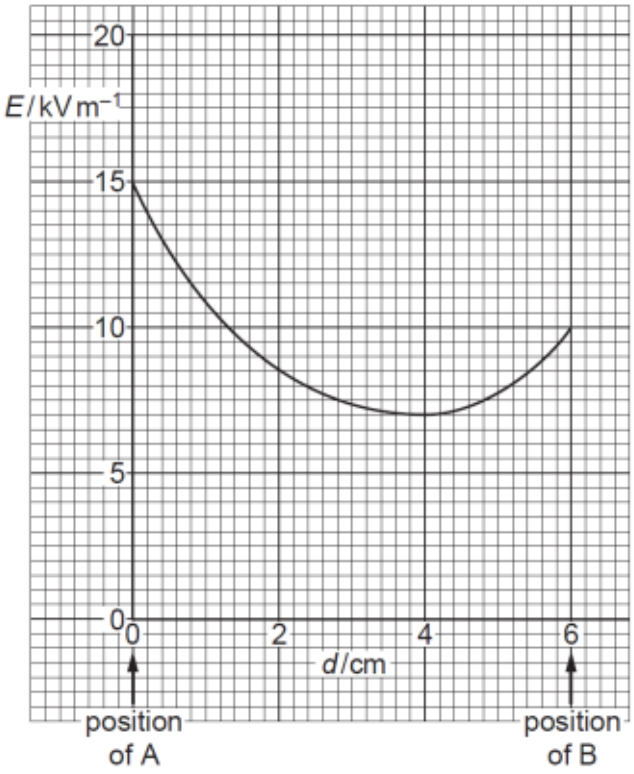


Fig. 3.2

(i) State and explain which feature of Fig. 3.2 shows that the point charge A and B are charges of opposite signs.

.....

.....

.....

..... [2]

(ii) Estimate the potential difference between A and B.

potential difference = ... V [3]

(iii) An electron is released from rest at B and travels towards A. Use your answer in **(b)(ii)** to calculate the speed of the electron just before it reaches point A.

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

4 At high pressures, a real gas does not behave as an ideal gas. For a certain range of pressures, it is suggested that the relation between the pressure p and volume V of one mole of the gas at constant temperature is given by the equation

$$pV = A + Bp$$

where A and B are constants.

In an experiment to measure the deviation of nitrogen gas from ideal gas behaviour, the volume V of the gas was measured for different values of the pressure p. Fig. 4.1 shows the readings obtained.

p / 10^6 Pa	V / 10^{-4} m^3	pV / N m
2.0	6.200	1240
6.0	2.000	1200
10.0	1.160	1160
14.0	0.800	
18.0	0.600	1080
22.0	0.473	1040

Fig. 4.1

(a) Complete Fig. 4.1 for $p = 14.0 \times 10^6$ Pa. [1]

(b) A graph of some of the data showing the variation of pV with p is shown in Fig. 4.2.

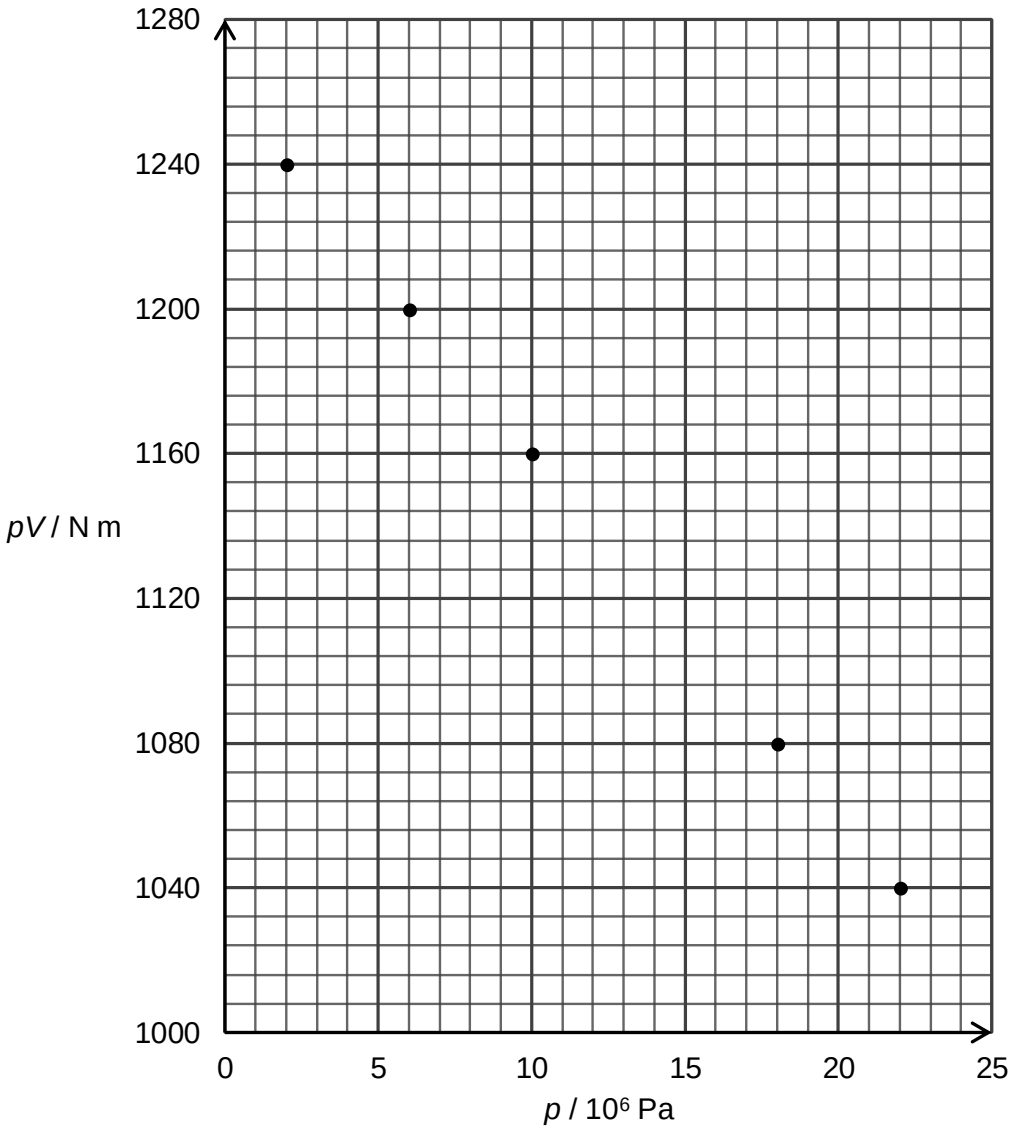


Fig. 4.2

(i) On Fig. 4.2, plot the point corresponding to $p = 14.0 \times 10^6$ Pa. [1]

(ii) Draw the line of best fit for all the points. [1]

(iii) Use the graph to determine the values of constants A and B.

A = ... N m [2]

B = ... m^3 [2]

(iv) Suggest why the value of B is negative.

.....

..... [1]

(v) For $p = 10.0 \times 10^6$ Pa, the measurements of p and V have percentage uncertainties of 5% and 3% respectively. Calculate the absolute uncertainty of the corresponding pV value.

$\Delta(pV)$ = ... N m [2]

(vi) Fig. 4.2 was based on an experiment conducted with 1 mole of real gas at a constant temperature of 150 K. State and explain the shape of the graph of pV against p if the experiment is conducted again with 1 mole of an ideal gas at the same temperature.

.....

.....

.....

..... [2]

5 **(a)** A pulse of an X-ray wave lasts for 1.0×10^{-10} s. A photon of the X-ray may be considered to be at a point anywhere within this pulse, although the location of the point is not known.

(i) Calculate the length of the pulse.

length of pulse = ... m [1]

(ii) State the uncertainty in the position of the photon.

uncertainty in position = ... m [1]

(iii) Calculate the uncertainty in the momentum of the photon.

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

(b) Fig. 5.1 shows the wave function of a particle incident on a potential barrier.

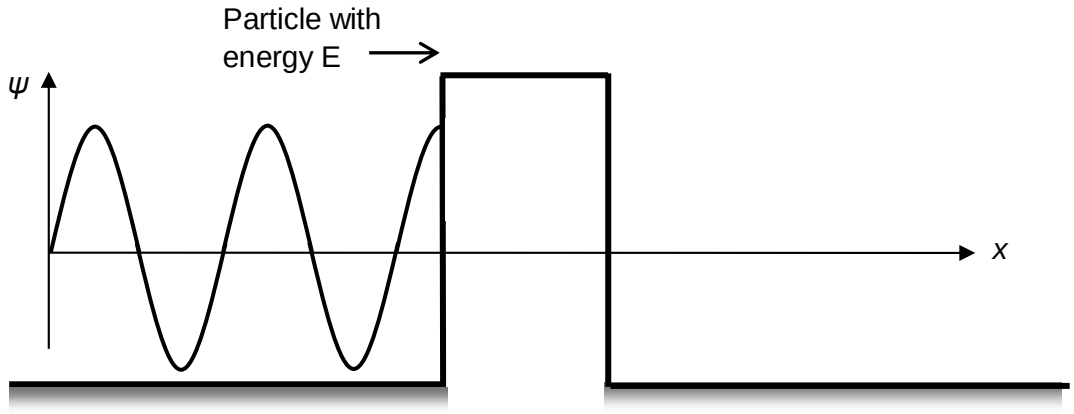


Fig. 5.1

(i) Explain what is meant by a potential barrier.

.....

..... [1]

(ii) By completing the wave function in Fig. 5.1, discuss how the wave nature of particles allows particles to tunnel through such a barrier.

.....

.....

.....

.....

..... [4]

(c) The tip of a STM probe is positioned at a distance *d* from a sample surface. The potential barrier has a height of 7.0 eV. Calculate the value of *d* at which the electrons of energy 1.0 eV have a transmission coefficient *T* of 0.0001.

d = ... m [2]

6 **(a)** Fig. 6.1 shows some of the energy levels of helium and neon.

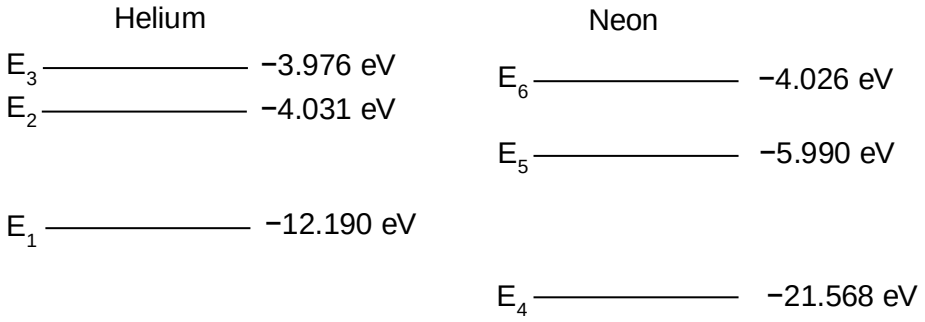


Fig. 6.1

(i) Energy level E_3 of helium is a metastable state. Explain what is meant by a metastable state.

.....

..... [1]

(ii) The transition between E_6 and E_5 gives rise to the emission of laser light. Determine the wavelength of the laser light produced.

wavelength = ... m [2]

(iii) Hence, state the colour of the laser light produced in **(a)(ii)**.

..... [1]

(b) Fig. 6.2 shows a p-type semiconductor placed in contact with an n-type semiconductor.

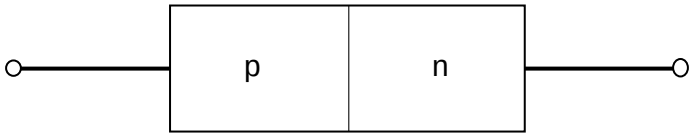


Fig. 6.2

(i) Explain how a depletion layer is formed between the p-type and n-type semiconductors.

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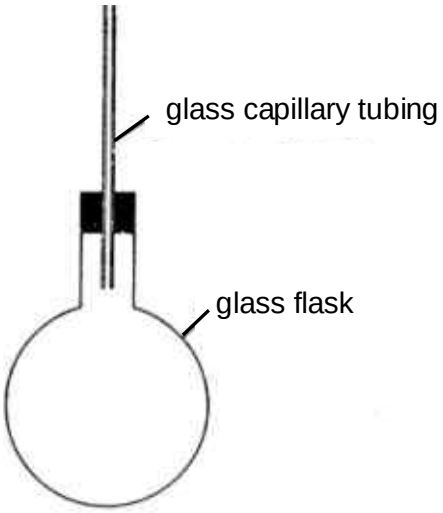
..... [4]

(ii) On Fig. 6.2, draw an e.m.f. source connected to the p-n junction in a manner so as to widen the depletion region. [1]

7 It is predicted that the average temperature of the Earth will increase by a few degrees over the next few hundred years. One consequence of this is that sea levels will rise due to the melting of the Antarctic ice cap, and the expansion of water in the oceans. In order for scientists to make any kind of estimate of how much the levels will rise, it is necessary to know how much expansion will occur for a given rise in temperature. It is known that the increase in volume of water per degree temperature rise is very small.

Design a laboratory experiment to determine how the total volume of a given amount of water changes with temperature.

The following equipment is available: a glass flask with a glass capillary tubing, and any other equipment normally available in a school laboratory. The inner diameter *d* of the glass capillary tubing is known.



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 initial volume of water would be accurately measured (you may assume that the density of water at the starting temperature is known),

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Name: _____

CG: **15S**_____

12

Diagram

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[Turn over

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MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/03

Paper 3 Longer Structured Questions **20 September 2016**

2 hours

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

Candidate Name: _____ Class _____ Reg No _____

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 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.

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	
Section A	
1	**/ 6**
2	**/ 12**
3	**/ 10**
4	**/ 12**
Section B	
5	**/ 20**
6	**/ 20**
7	**/ 20**
Deductions	
Total	**/ 80**

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	=	ρgh
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	=	$v_o \cos \omega t$
	v	=	$\pm \omega\sqrt{x_o^{\,2} - x^2}$
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	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows a light gate, which is an electronic sensor used to measure the speed of an object. The light gate consists of an infrared beam which travels between its two arms. The light gate is triggered when the beam is blocked by the object, and the time duration of the obstruction is recorded using a data logger (not shown).

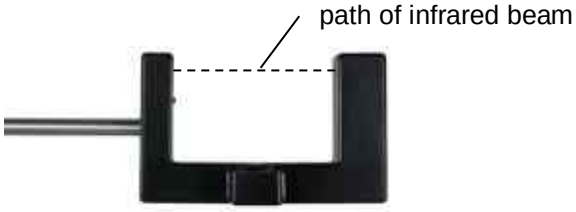


Fig. 1.1

A weighted card is released and falls vertically through the light gate, as shown in Fig. 1.2.

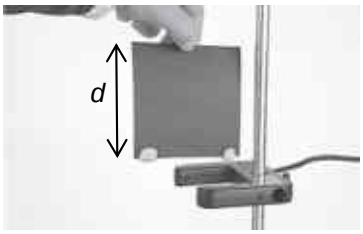


Fig. 1.2

The card has a length d = (0.200 ± 0.002) m, and the time taken for the card to travel through the light gate was t = (0.06428 ± 0.00001) s.

(a) Calculate the average speed of the card. Express it with its associated uncertainty.

speed = (.....±.....) m s^{-1} [3]

(b) Suggest two reasons why, with a single light gate, we can only measure the average speed of the falling card, but not its instantaneous velocity.

Reason 1: .....

.....

Reason 2: .....

..... [2]

(c) Suggest a source of random error that limits how precisely the speed can be measured.

..... [1]

2 **(a)** **(i)** State how a polarised transverse wave differs from an unpolarised transverse wave.

.....

.....

..... [2]

(ii) Suggest how it can be verified that a laser light is plane-polarised.

.....

..... [1]

(b) Fig. 2.1 shows the variation with distance of the displacement of the points along a string when a transverse wave propagates along the string.

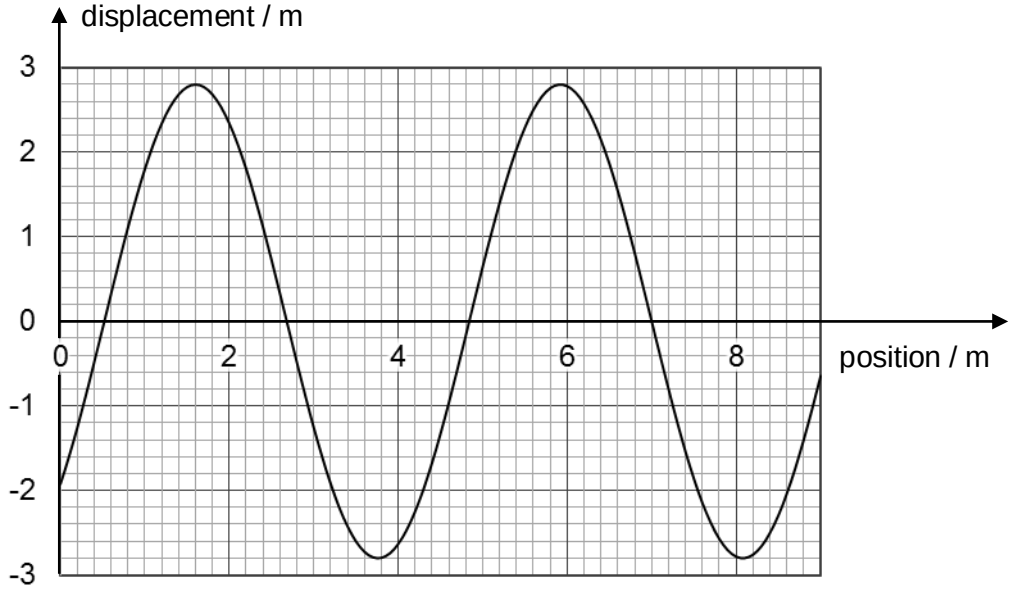


Fig. 2.1

State and explain why the speed of the wave cannot be determined from Fig. 2.1.

.....

..... [2]

(c) Fig. 2.2 shows a double slit arrangement to demonstrate observable interference of light on the screen.

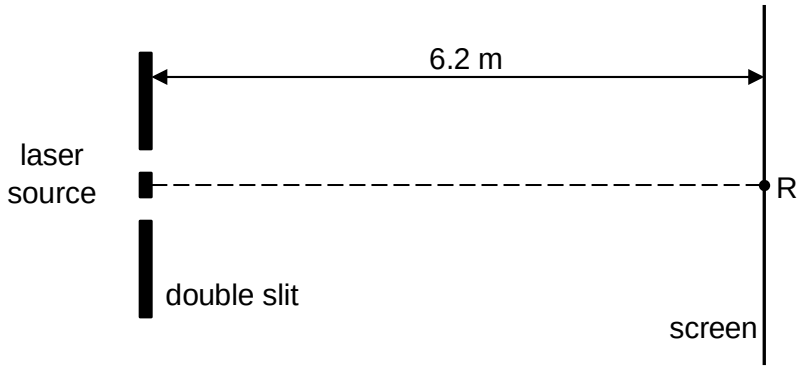


Fig. 2.2

(i) Suggest why a laser source is used.

.....

..... [1]

(ii) The separation between the two slits is 0.80 mm. The fringe separation observed on the screen is 5.0 mm. Determine the wavelength of the laser light used.

wavelength = ... m [2]

(iii) The screen is now moved further from the slits. Explain what happens to the intensity of light reaching point R on the screen.

.....

.....

..... [2]

(d) A standing sound wave is set up within a pipe with both ends open. Two nodes are observed within the pipe. The pipe is 1.5 m long. The speed of sound is 330 m s^{-1}.

Sketch the profile of the standing wave formed in the pipe on Fig. 2.3 and calculate the frequency of the sound.

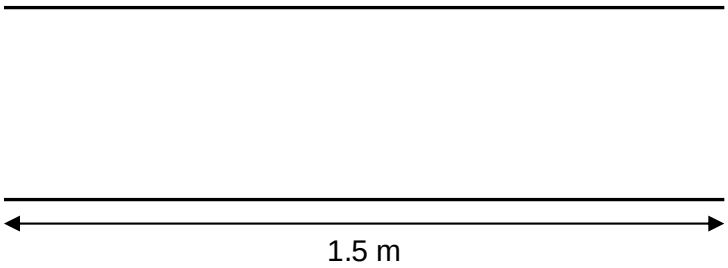


Fig. 2.3

frequency = ... Hz [2]

3 Five identical electrical devices of resistance 10 Ω and three switches, S_A, S_B and S_C, are arranged in a network as shown in Fig. 3.1. S_A is open while S_B and S_C are closed.

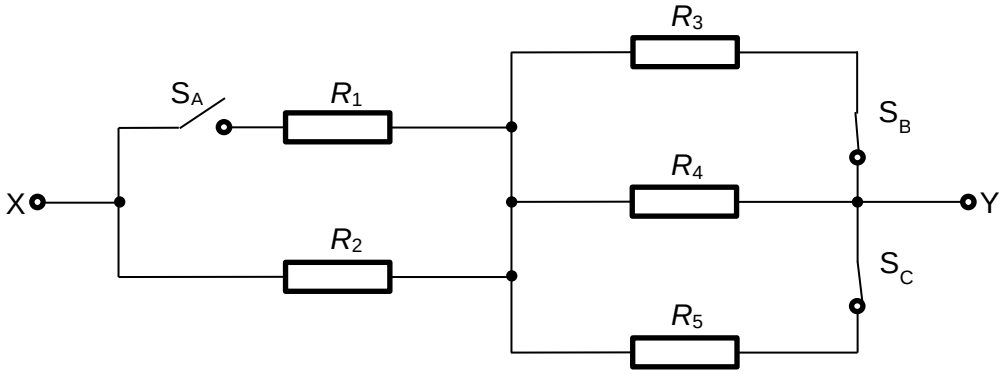


Fig. 3.1

(a) Determine the value of R_{XY}, the resistance between terminals X and Y.

R_{XY} = ... Ω [2]

(b) The network is now connected to a cell of e.m.f. 3.0 V with an internal resistance of 0.40 Ω as shown in Fig. 3.2.

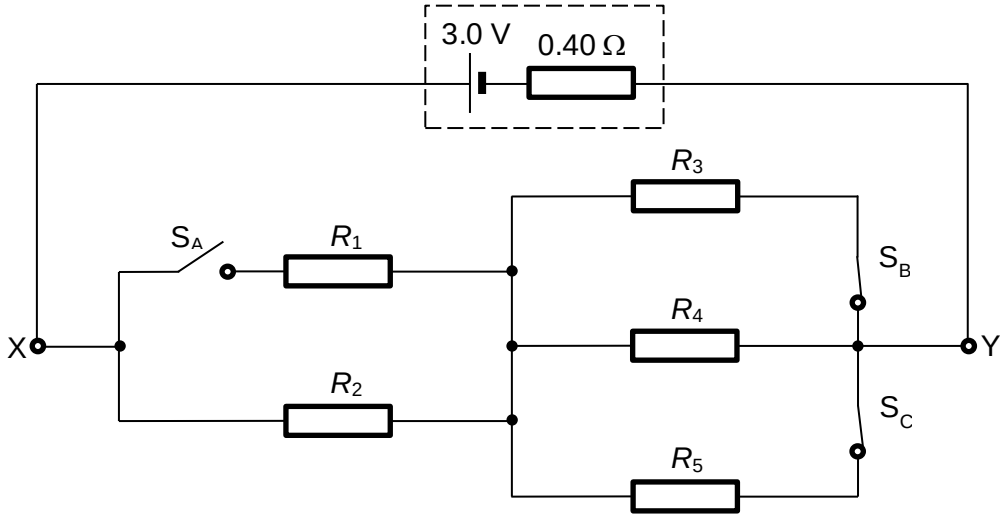


Fig. 3.2

(i) Determine the current supplied by the cell.

current = ... A [2]

(ii) Calculate the power dissipated in R_3.

power = ... W [2]

(c) Ideal diodes have infinite resistance when they are in reverse bias and zero resistance when they are in forward bias. The switches in Fig. 3.2 can be replaced with ideal diodes to obtain the same circuit.

Complete Fig. 3.3 below with the diodes in suitable orientations. [2]

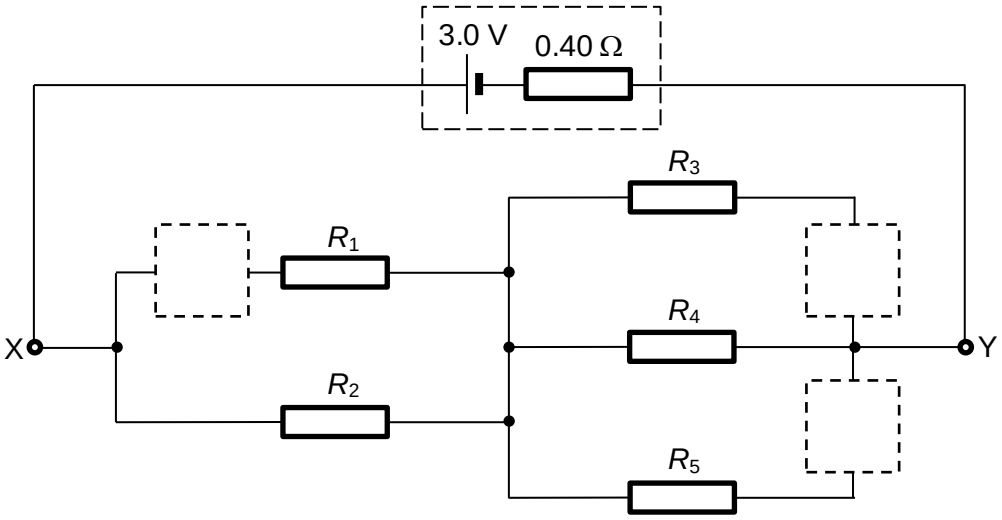


Fig. 3.3

(d) Briefly explain why, in practice, a diode requires a small forward biased potential difference across its terminals before current can flow through it.

.....

.....

.....

..... [2]

4 **(a)** Distinguish between a line emission spectrum and a line absorption spectrum in terms of their appearance.

.....

.....

..... [2]

(b) Explain how a line emission spectrum is obtained.

.....

.....

.....

.....

.....

..... [3]

(c) Explain how a line spectrum can be used to identify the elements in a sample of gas.

.....

.....

..... [2]

(d) Some of the energy levels of a particular atom X are shown in Fig. 4.1.

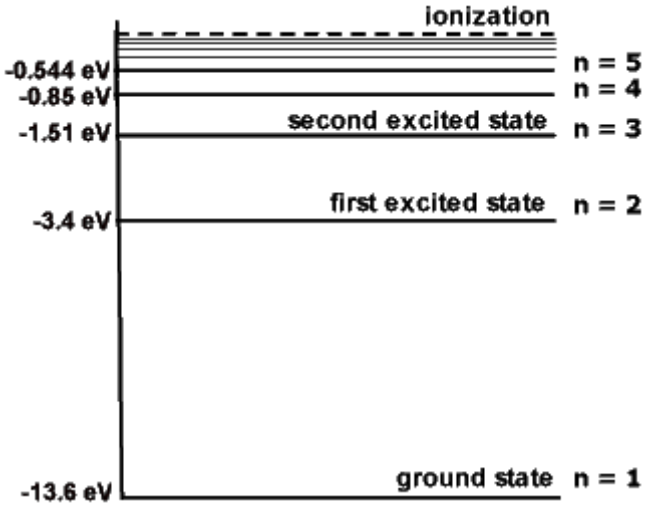


Fig. 4.1

(i) State the ionisation energy of atom X.

..... [1]

(ii) Cool vapour of X at low pressure is bombarded with electrons of kinetic energy 2.00×10^{-18} J. With appropriate calculations, state and explain the transition(s) you would expect to observe.

.....

..... [2]

(iii) If the electrons were replaced with photons of the same energy, state and explain on the difference in your observation.

.....

.....

..... [2]

Section B

Answer **two** questions from this Section in the spaces provided.

5 (a) (i) State Newton's law of gravitation.

.....

.....

..... [1]

(ii) Explain why the gravitational forces are significant only with celestial objects like stars and planets but not with atoms or molecules.

.....

..... [1]

(iii) A man stands on a weighing machine at the pole and then at the equator. Assuming Earth to be a perfect sphere, explain with the help of diagrams why there is a difference in the readings of the weighing machine.

.....

.....

.....

..... [3]

(b) A satellite of mass m is in a circular orbit about the Earth with a constant speed.

(i) Explain whether the satellite is in equilibrium.

.....

..... [1]

(ii) Derive the expression of kinetic energy of the satellite in terms of the mass of Earth M, the mass of the satellite m, and the orbital radius r. [2]

(iii) The potential energy of a satellite at the surface of the Earth is -9.6×10^{10} J. A satellite is launched close to one of the poles of the Earth. Calculate the minimum energy supplied to the satellite to put it into an orbit of radius 4.3×10^{4} km. The radius of the Earth is 6.4×10^{3} km.

minimum energy = ...J [4]

(iv) The same satellite is now launched from the surface of the Earth at the equator to the same orbit. Explain why the minimum energy supplied to the satellite will be lower compared to that calculated in **(b)(iii)**.

.....

..... [1]

(v) A satellite in a low orbit around the Earth will experience resistive forces due to the Earth's atmosphere. State and explain what will happen to the height of the satellite and its speed.

.....

.....

.....

..... [2]

(c) **(i)** Show that for any satellite in an orbit of radius R,

$$\frac{R^3}{T^2} = \text{constant}$$

where T is the orbital period of the satellite. [1]

(ii) A satellite orbiting at a height of $0.1R_E$ above the surface of the Earth has a rotating period of 5100 s. Using **(c)(i)**, calculate the orbital radius of a geostationary satellite in terms of R_E, the radius of the Earth.

orbital radius = ... [2]

(iii) List one advantage and one disadvantage of a geostationary satellite.

Advantage: .....

.....

Disadvantage: .....

..... [2]

6 **(a)** A sinusoidal alternating supply voltage is connected across the primary coil of an ideal iron-cored transformer. The secondary coil is connected to a resistor. This is shown in Fig. 6.1.

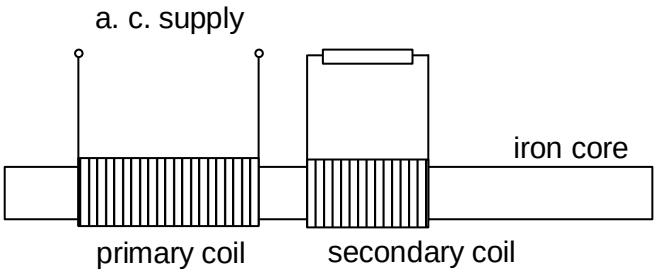


Fig. 6.1

(i) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

The secondary coil has 500 turns and cross-sectional area of 0.010 m^2. With the a.c. supply connected, it is subjected to a changing magnetic field. The variation with time of magnetic flux density in the secondary coil is shown in Fig. 6.2.

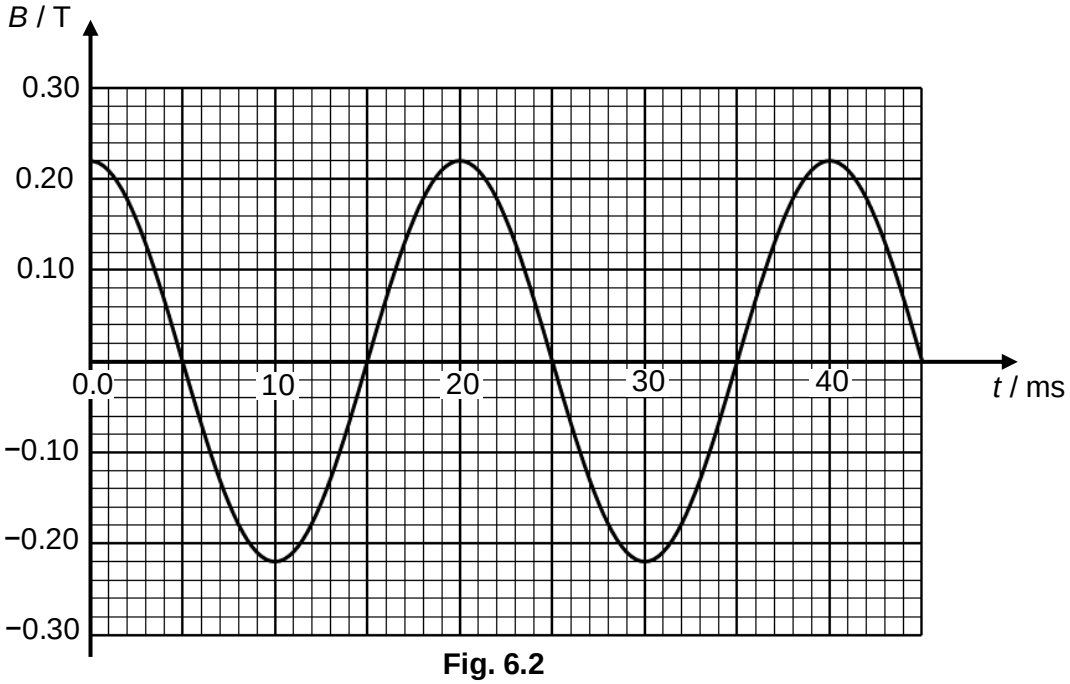


Fig. 6.2

(ii) Estimate the maximum value of the induced e.m.f.

maximum e.m.f. = ...V [3]

(iii) Sketch and label in Fig. 6.3 the corresponding graph of the induced e.m.f. against time from $t = 0$ to $t = 40$ ms. [2]

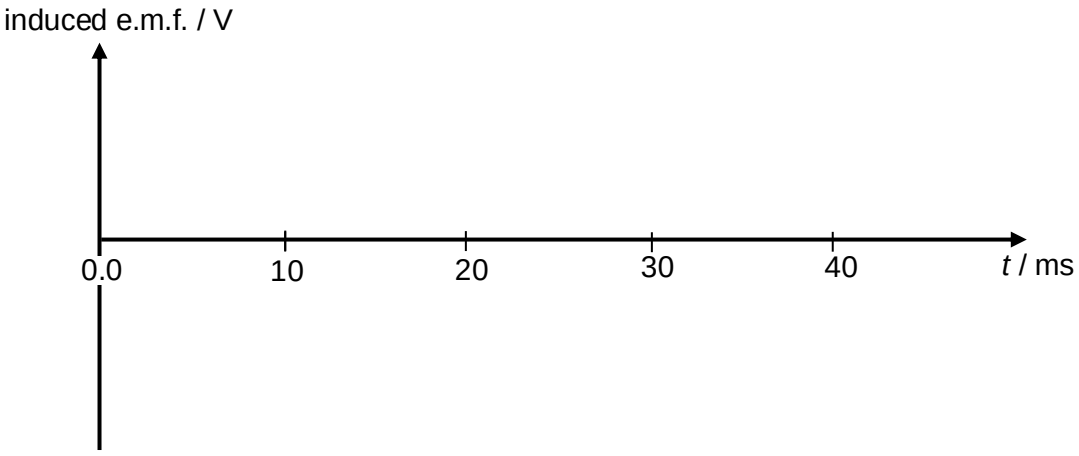


Fig. 6.3

(iv) The resistor in the secondary coil has a resistance of 8.0 Ω. Calculate the root-mean-squared current passing through the resistor.

root-mean-squared current = ...A [3]

(v) The primary coil contains 3200 turns. Calculate the value of the peak e.m.f. in the primary coil.

peak e.m.f. = ...V [2]

(vi) The iron core is now removed. Explain why the peak e.m.f. in the secondary coil decreases.

.....

.....

..... [2]

(b) (i) Define *magnetic flux density*.

.....

..... [1]

A particle of charge q and mass m is moving in a helical path inside a uniform magnetic field of magnetic flux density B. It has a velocity of v and makes an angle of θ with the magnetic field as shown in Fig. 6.4.

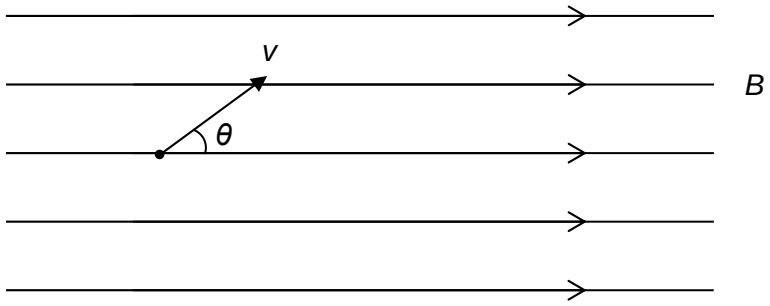


Fig. 6.4

(ii) Show that the radius of the helical path r is given by the expression [2]

$$r = \frac{mv \sin\theta}{Bq}$$

(iii) Hence, or otherwise, show that the period of each cycle of the helical path is independent of θ. [2]

(iv) Explain why there is no work done by the magnetic field on the electron.

.....

..... [1]

7 **(a)** It is said that, in theory, 3 bottles of water and a few rocks can power an average home for a year. The water and rocks can be used to obtain raw materials for nuclear fusion reactions between deuterium and tritium.

The following data list the masses of various nuclei used in these reactions:

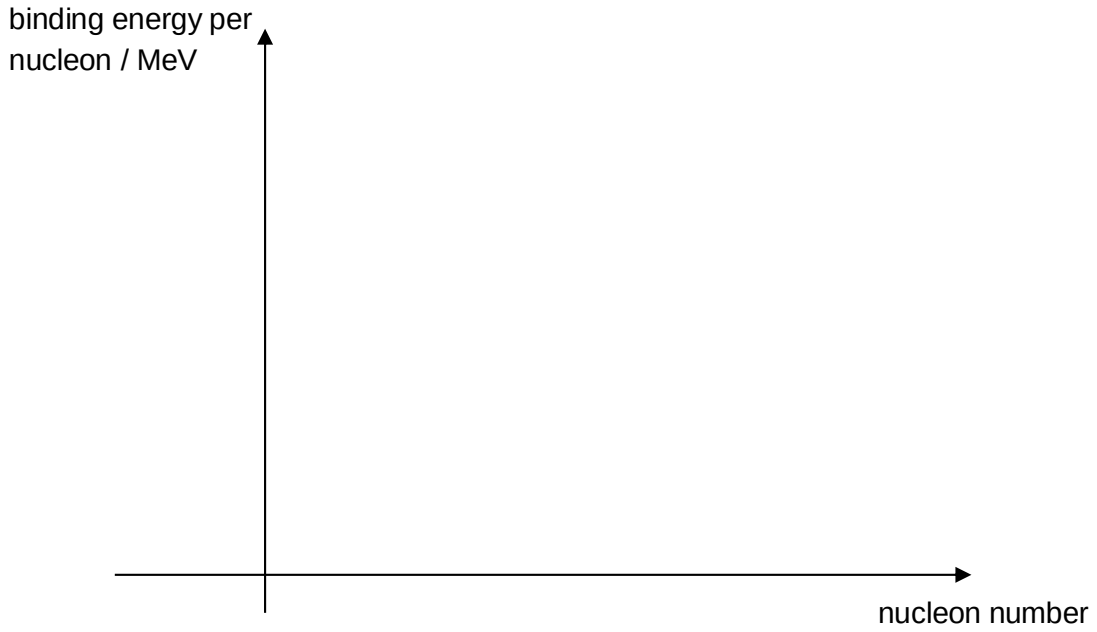
neutron		1.008664 u
proton		1.007276 u
deuterium	$^{2}_{1}H$	2.014102 u
tritium	$^{3}_{1}H$	3.016049 u
helium-4	$^{4}_{2}He$	4.002602 u
lithium-6	$^{6}_{3}Li$	6.015122 u

Tritium $^{3}_{1}H$ can be made from lithium $^{6}_{3}Li$ which can be extracted from the rocks.

(i) Calculate the binding energy per nucleon of a $^{6}_{3}Li$ nucleus.

binding energy per nucleon = ...J [3]

(ii) Sketch on the axes below, a labelled graph to show the variation of binding energy per nucleon with nucleon number. [1]



(iii) Deuterium can be extracted from the water. Thermonuclear reactors heat a mixture of deuterium and tritium to 100 million degrees Celsius to produce the reaction:

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n} + \gamma$$

Calculate the amount of energy in MeV produced in one such reaction.

energy produced = ... MeV [2]

(iv) Explain why it is necessary for the temperature of the reaction to be so high.

.....

.....

..... [2]

(b) Technetium-99* $\left({}^{99}_{43}Tc^{*}\right)$ is a common isotope used in nuclear medicine. The mass of ${}^{99}_{43}Tc^{*}$ is 98.9063u. The symbol * means it is an excited state.

Technetium-99* can be introduced into the body. The gamma rays that it produces are detected outside the body and used to make images of various organs.

Technetium-99* decays with a half-life of *x* hrs as follows:

$$ {}^{99}_{43}Tc^{*} \rightarrow {}^{99}_{43}Tc + \gamma $$

The product, Technetium-99, then further decays by emitting low energy beta particles.

$$ {}^{99}_{43}Tc \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}e $$

The half-life of Technetium-99 is 211000 years.

(i) The radioactive decay of the isotope Tc-99* is both spontaneous and random.

Explain what is meant by

1. radioactive decay,

.....

.....

..... [2]

2. spontaneous process,

.....

.....

..... [1]

3. random process.

.....

.....

..... [1]

Fig. 7.1 shows the decay curve of a freshly administered dose of Technetium-99*.

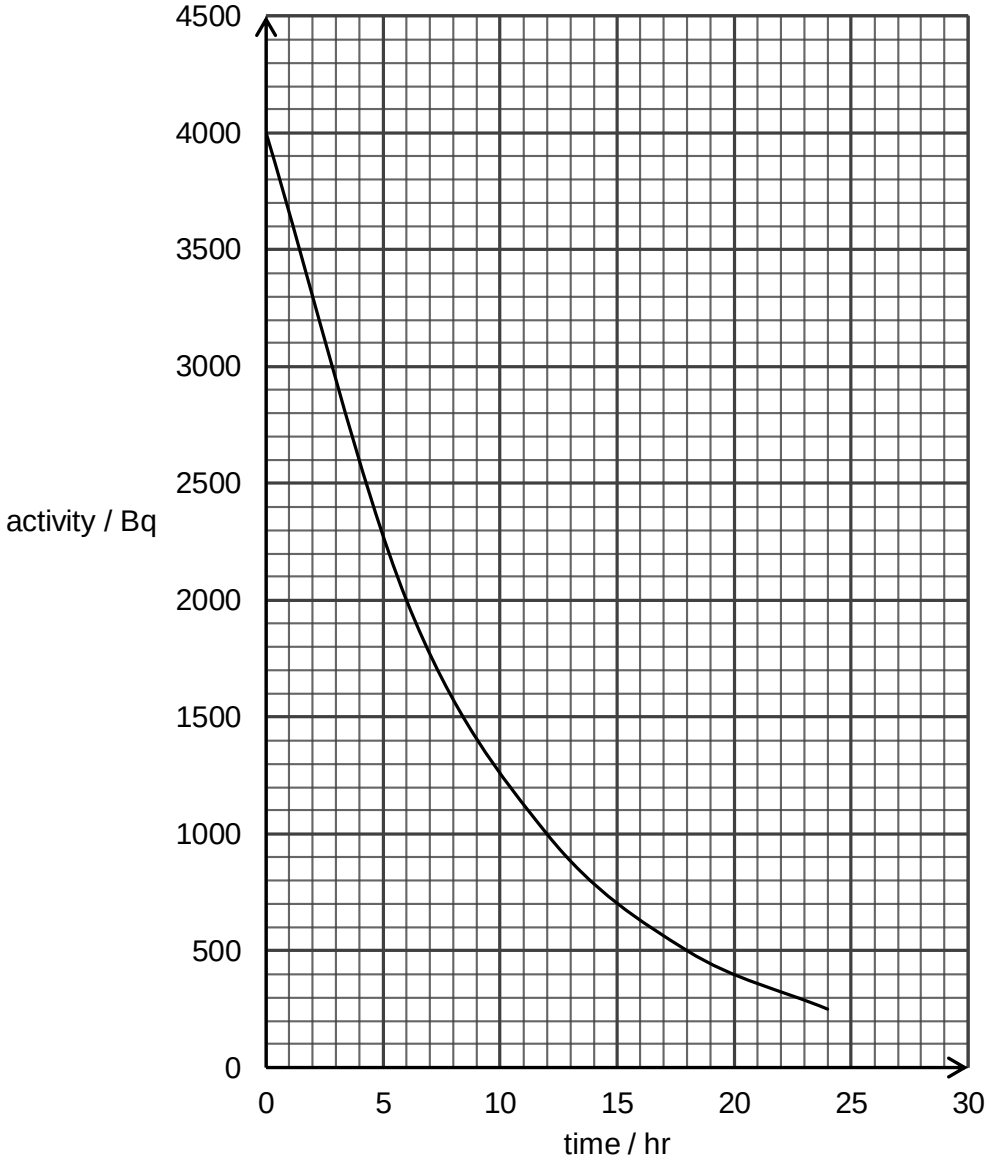


Fig 7.1

(ii) State the half-life of Technetium-99*, *x*, in terms of hours.

x = ...hours [1]

(iii) Determine the mass of Technetium-99* remaining in the body after 30.0 hours.

mass = ...kg [4]

(iv) With reference to the half-lives of both Technetium-99* and Technetium-99, explain why Technetium-99* is suitable for use in medical imaging.

.....

.....

.....

..... [2]

(v) Explain why it is safer to use gamma-emitting radioisotopes than alpha-emitting radioisotopes in nuclear medicine.

.....

..... [1]

Proposed solutions for H2 Physics Prelim P1

1	**B**	**21**	**A**
2	**B**	**22**	**D**
3	**C**	**23**	**D**
4	**D**	**24**	**C**
5	**C**	**25**	**D**
6	**B**	**26**	**C**
7	**D**	**27**	**A**
8	**D**	**28**	**B**
9	**C**	**29**	**B**
10	**A**	**30**	**A**
11	**A**	**31**	**A**
12	**B**	**32**	**D**
13	**C**	**33**	**C**
14	**A**	**34**	**C**
15	**D**	**35**	**A**
16	**D**	**36**	**A**
17	**D**	**37**	**B**
18	**C**	**38**	**C**
19	**B**	**39**	**D**
20	**B**	**40**	**C**

Q1: B

$F = BIL$

$$B = \frac{F}{IL} = \frac{ma}{IL}$$

$$\text{Base unit of } B = \frac{\text{kg m s}^{-2}}{\text{A m}}$$
$$= \text{kg s}^{-2}\ \text{A}^{-1}$$

Q2: B

A Both vectors
B Magnetic flux density: vector, kinetic energy: scalar
C Both scalars
D Both scalars

Q3: C

Let the total distance be S and the total time t.

Since the stone falls 0.75S in the last two seconds of its fall, it travels 0.25S in the first (t-2) seconds.

$$\frac{1}{2}g(t-2)^2 = 0.25S$$

$$\frac{1}{2}g(t-2)^2 = 0.25(\frac{1}{2}gt^2)$$

$$(t-2)^2 = 0.25t^2$$

$$t-2 = 0.5t$$

$$t = 4.0\,\text{sec}$$

Q4: D

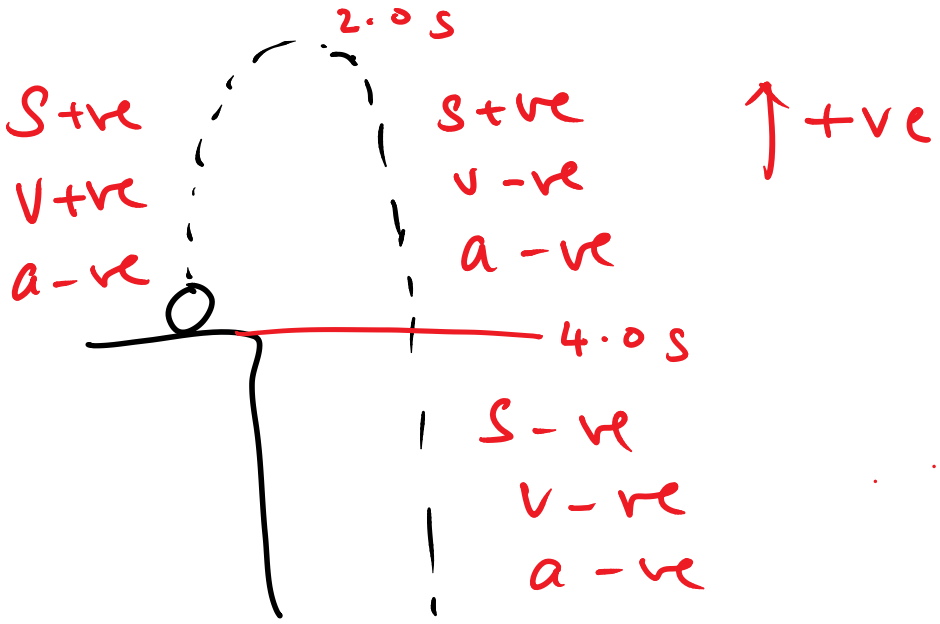
Since the stone takes 2.0 s to reach its highest point, at 4.0 s it will have reached the point of S = 0.

Taking upwards as positive,

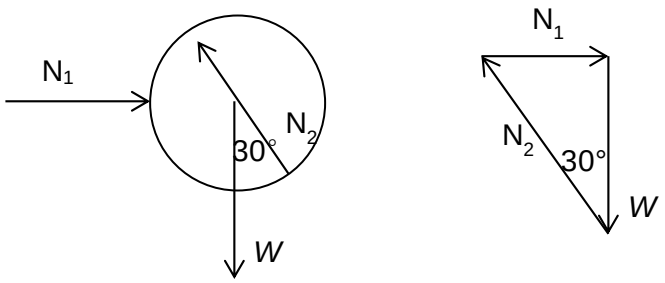
Option A incorrect – Stone is on its upwards motion. The displacement and velocity is positive and the acceleration is negative.

For option B and C, the stone is on its downwards motion but has not reach the point of S = 0. Hence displacement is positive, velocity and acceleration are negative.

Option D correct – the stone is on its downward motion (having passed the point of S = 0) with negative displacement. Velocity and acceleration are negative.



Q5: C



Using force diagram and resolving horizontally and vertically,

$N_2 \sin 30 = N_1$ (1)

$N_2 \cos 30 = W$ (2)

$\frac{(1)}{(2)}$: $\tan 30 = \frac{N_1}{W}$

(Alternative: Using vector triangle)

$N_1 = W \tan 30 = 15 \tan 30 = 8.66 = 8.7$ (2s.f.)

Q6: B

When reading is more than F, means that upward force by spring balance on mass is greater than weight of mass. Net force upwards – acceleration directed upwards.

Q7: D

Since particle Y is stationary (no KE nor momentum),
Initial KE of system is *E*, initial momentum of system is *p*.
Collision is inelastic – final kinetic energy of system should be less than *E* (Option C or D)
Momentum of any collision must be conserved, final momentum of system should be still *p*.

Full working:
Conservation of momentum, $mu + 0 = 2mv \rightarrow v = \frac{1}{2} u$
System: Total $p = 2mv = 2m (\frac{1}{2} u) = mu = p$
Total KE = $\frac{1}{2} (2m)(v^2)$
$= \frac{1}{2} (2m) (\frac{1}{2}u)^2 = \frac{1}{2} (\frac{1}{2} mu^2) = \frac{1}{2} E$
X: $p = mv = m (\frac{1}{2} u) = \frac{1}{2} p$
KE = $\frac{1}{2} mv^2$
$= \frac{1}{2} (m) (\frac{1}{2}u)^2 = \frac{1}{4} (\frac{1}{2} m u^2) = \frac{1}{4} E$

.

Q8: D

Both boats travel the same distance *s* and experience the same force *F*. Hence the total work done by the force *F* between the starting line and the finish line is the same for each boat – they will have the same final kinetic energy.

Boat with mass *m* will experience a larger acceleration, and will thus reach the finish line first.

Note: Boat with mass *m* will also have a higher speed, since the two boats have the same final kinetic energy.

Q9: C

Section C has the steepest gradient, indicating the highest velocity. Since *P=Fv*, this section has the greatest work done per unit time against friction.

Q10: A

By conservation of energy, elastic potential energy is converted to kinetic energy and work done against friction. As height is the same at initial and final positions, gravitational potential energy is unchanged.

$$EPE_{loss} = KE_{gain} + WD_{\text{friction}}$$

$$\frac{1}{2}kx^2 = \left(KE_{final} - KE_{initial}\right) + fd$$

$$KE_{final} = \frac{1}{2}kx^2 - fd \qquad \left(KE_{initial} = 0\right)$$

Q11: A

Displacement is zero, thus average velocity is zero since average velocity is total displacement over time taken.

Therefore, average momentum is zero. ($p = mv$)

Q12: B

$$N\sin\theta = mg$$

$$N\cos\theta = \frac{mv^2}{r}$$

$$\Rightarrow \tan\theta = \frac{rg}{v^2}$$

$$\theta = \tan^{-1}\left(\frac{rg}{v^2}\right)$$

Q13: C

A: $\phi = \dfrac{GM}{r} \Rightarrow \phi \propto \dfrac{1}{r}$

B: $KE = \dfrac{1}{2}\dfrac{GMm}{r} \Rightarrow KE \propto \dfrac{1}{r}$

C: Negative work done by external force as external force points rightwards and the displacement is leftwards. However, positive work is done by the gravitational force.

D: $W = \Delta U = m\Delta\phi$

Q14: A

Gravitational field strength on the surface of the Earth is $g_0 = \dfrac{GM}{R^2} = \dfrac{4GM}{d^2}$ …..(1)

At the position of the satellite, Earth's gravitational field strength is $g = \dfrac{GM}{r^2} = \dfrac{GM}{(30d)^2}$ ……(2)

$$\frac{g}{g_0} = \frac{1}{(30^2)4}$$
$$g = \frac{10}{(30^2)4}$$
$$= 2.8 \times 10^{-3} \text{ N kg}^{-1}$$

Q15: D

$$x = x_o \cos(\omega t)$$
$$= 0.050 \cos(2\pi \times 2.0 \times 1.7)$$
$$= -0.0405 \text{ cm}$$
$$|a| = |\omega^2 x| = (2\pi \times 2)^2 (0.0405) = 6.40 \text{ m s}^{-2}$$

Q16: D

The period of the forced oscillation at resonance increases when the system is damped. (The resonance frequency decreases.)

Q17: D

A Incorrect: Ice is less dense than water at around 0 °C, so ice molecules are further apart.
B Incorrect: Mean kinetic energy of the water molecules is a measure of temperature. Since all 3 phases co-exist at triple point, they have the same temperature and hence same mean kinetic energy
C Incorrect: Mass of each molecule in solid, liquid and gaseous phase are the same. Only volume and therefore density differs.
D Correct: as temperature is proportional to mean kinetic energy of the molecules, at the same temperature (triple point) and same mass per molecule, the r.m.s. speed is the same.

Q18: C

T_1 is higher temperature than T_2.

From $\Delta U = Q + W$

	T	ΔU	W_{on}	Q	
A	Increase	Positive	Expand → Negative	Need to be positive	Wrong
B	Increase	Positive	Zero	Need to be positive	Wrong
C	Increase	Positive	Contract → Positive	can be positive, zero or not < $-\|W_{on}\|$	Correct
D	No change	Zero	Contract → Positive	Need to be negative	Wrong

Q19: B

P and Q will move in opposite direction regardless of direction of wave propagation. If the wave moves rightwards, P will be displaced less positive (moving leftwards) while Q will be displaced positive (moving rightwards).

Q20: B

$$\lambda_1 = \frac{v}{2400}$$

$$\lambda_2 = \frac{v}{2800}$$

At 2800 Hz the path difference has 1 more λ than at 2400 Hz

Number of wavelengths occupying 0.70 m $= \frac{0.7}{\lambda_2} = \frac{0.7}{\lambda_1} + 1$

$$\frac{0.70 \times 2800}{v} = \frac{0.70 \times 2400}{v} + 1$$

$$v = 280 \text{ m s}^{-1}$$

Q21: A

$$d = \frac{\lambda L}{x}$$

$$d_{new} = \frac{(2\lambda)(0.5L)}{4x} = 0.25\frac{\lambda L}{x} = 0.25d$$

Q22: D

$$d\sin\theta = n\lambda$$

$$\frac{1\times10^{-3}}{500}(1) = n_{\max}\left(600\times10^{-9}\right)$$

$$n_{\max} = 3.33$$

Total number of fringes = 3 + 1 + 3 = 7

Q23: D

By conservation of energy

gain in electric potential energy = loss in kinetic energy

$$(qE)x = \frac{1}{2}mv^2$$

$$(eE)x = \frac{1}{2}mv^2$$

$$x = \frac{mv^2}{2Ee}$$

Q24: C

The electric potential energy of the original system is

$$U = \frac{(q)(q)}{4\pi\varepsilon_o(d)} = \frac{q^2}{4\pi\varepsilon_o d}$$

In bringing the negative point charge into the system, the change in the electric potential energy,

$$\Delta U = \frac{(q)(-2q)}{4\pi\varepsilon_o\left(d/2\right)} + \frac{(q)(-2q)}{4\pi\varepsilon_o\left(d/2\right)} = \frac{(-8)q^2}{4\pi\varepsilon_o d} = -8U$$

Therefore the electric potential energy of the new system is

$$U_{new} = U + (-8U) = -7U$$

Q25: D

When $I = 0$, $E = 2.5\ V$

$$V = E - Ir$$

Substituting point from graph,

$$1.2 = 2.5 - 1.7r$$

$$r = 0.76\ \Omega$$

Q26: C

Option A is a true statement. The metallic conductor obeys Ohms Law and the IV characteristics is a straight line P passing through origin while Q represents a thermistor's IV characteristics as the resistance of semiconductor diode decreases with increasing forward biased voltage.
Option B is a true statement. As graph Q illustrates that as current increases, its resistance decreases.
Option C is a false statement. As At 1.9 A, both P and Q have the same p.d. Hence they have the same resistance. The resistance is not given by the reciprocal of the gradient at current 1.9 A
Option D is a true statement. The power can be determined as product IV. At 0.5 A, pd across Q is twice of that of P, hence power dissipated is twice.

Q27: A

A: $I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{1+2+2} = 0.2V_{PQ}$

B: $I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{\left(\frac{1}{1}+\frac{1}{2}\right)^{-1}+2} = \frac{V_{PQ}}{8/3} = 0.375V_{PQ}$

C: $I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{1+2} = \frac{V_{PQ}}{3} = 0.333V_{PQ}$

D: $I_{ammeter} = \frac{V_{PQ}}{R_{ammeter}} = \frac{V_{PQ}}{2} = 0.5V_{PQ}$

Q28: 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,

$R_{total} = R + R + R = 3R$

$I_{total} = \dfrac{V}{3R} = 0.33\dfrac{V}{R} = I_{bulb1} = I_{bulb2} = I_{bulb4}$

$\therefore I_{bulb1}$ and I_{bulb4} decreased, I_{bulb2} increased

since brightness $\propto$ power dissipated $= I^2R$

bulbs 1 and 4 became dimmer, bulb 2 became brighter

Q29: B

At point P,

(1) Magnetic field due to S is upwards (small magnitude due to larger distance)

(2) Magnetic field due to Q (towards R)

(3) Magnetic field due to R (away from Q) – magnitude same as 2)

The horizontal components of (2) and (3) point in exact opposite direction. Net horizontal component is zero.

Therefore, resultant of (2) and (3) point downwards (with a larger magnitude than that of "S")

Q30: A

Direction: By Fleming's left hand rule, a magnetic force acts into the paper along CD and out of the paper along EF. Hence, viewing from the top, the rotation is clockwise.

Magnitude:

$$F = BIL$$
$$= 0.010 \times 2.0 \times 0.25$$
$$= 0.0050 \text{ N}$$

Torque $= Fd = 0.0050 \times 0.25 = 1.3 \times 10^{-3}$ Nm

Q31: A

Using Faraday's law,

$$|\varepsilon| = \frac{dN\phi}{dt}$$
$$= NA\frac{\Delta B}{\Delta t}$$
$$NA = |\varepsilon|\frac{\Delta t}{\Delta B} = 13\left(\frac{0.5}{0.2}\right)$$
$$= 32.5 \text{ m}^2$$
$$= 50 \times 0.65$$

Q32: D

Electrons either accumulate in the centre or at the rim. In either case, 2 points equidistant from O will have the same potential, and the difference in potential between O and a point gets larger with distance. Therefore, $E_{PQ} = E_{QS}$.

Since points further from O travel faster, the length PQ cuts flux faster than QO. Therefore, $E_{PQ} > E_{QO}$

Q33: C

Since current is directly proportional to the magnetic field strength it generates, an alternating current is in phase with the magnetic flux linkage it generates. However, as e.m.f. induced in the secondary coil is proportional to the rate of change of magnetic flux linkage with respect to time, the alternating current in the secondary coil will be $\frac{\pi}{2}$ out of phase with the primary circuit. A more formal proof follows.

$$I_{secondary} = \frac{\varepsilon}{R}$$

$$= \frac{1}{R}\frac{dN\phi}{dt} \qquad \left(\varepsilon = \frac{dN\phi}{dt}\right)$$

$$= \frac{NA}{R}\frac{dB}{dt} \qquad (\phi = BA)$$

$$= \frac{NA\mu n}{R}\ \frac{d}{dt} I_{primary} \qquad (B = \mu n I) \text{ solenoid}$$

E.g. if the primary AC followed a sine curve, the secondary AC will follow a cosine curve.

Q34: C

The gain on the y- axis indicates and e.m.f. amplitude of 10 V, while the period of 8.0 s provides a value of 0.785 rad s^{-1} for the angular frequency. These are hence substituted into $\varepsilon = V_o \sin \omega t$

Q35: A

In the photoelectric experiment, photons are shone on the metal surface.

Hence by COE, the energy of the incoming photon = the least energy required to release a photoelectron + the maximum kinetic energy of the photoelectron.

Q36: A

The visible spectrum ranges from 400 nm (violet) to 700 nm (red).

$$\text{Energy of a red light photon} = = \frac{hc}{\lambda}$$

$$= \frac{6.63\times10^{-34}(3.00\times10^{8})}{7.0\times10^{-7}}$$

$$= 2.84\times10^{-19}\,\text{J}$$

$$= 1.77\ \text{eV}$$

Q37: B

For d_1 (conductor) the valence band and the conduction band overlap and electrons may freely move among the empty energy levels, thus able to move through the material.

For d_2 (semiconductor) there is a small energy gap between the valence band and the conduction band. When heated, valence electrons gain sufficient energy to jump across the gap and become conduction electrons.

For d_3 (insulator) the energy gap between the conduction band and valence band are too large for electrons to jump across, hence conduction cannot take place.

Q38: C

laser will still diffract slightly – not possible to be perfectly collimated.

Q39: D

$$BE \text{ per nucleons} = \frac{BE}{\text{number of nucleons}} = \frac{c^2\Delta m}{P}$$

Q40: C

$12000 = 20000\ e^{-\lambda(18)}$

$\lambda = 0.02837920132\ \text{min}^{-1}$

$t_{1/2} = 24.4\ \text{min}$

Proposed solutions to JC2 H2 Physics Prelim Paper 2

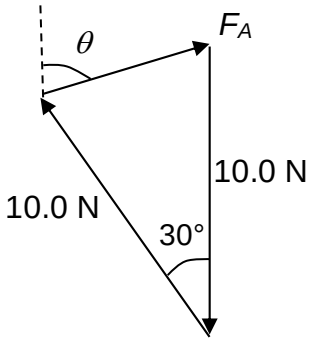
1 (a) (i)

$10 \sin 30° - F_A \sin\theta = 0$ or $10 \sin 30° = F_A \sin\theta$

$10 \cos 30° + F_A \cos\theta - 10 = 0$ or $10 \cos 30° + F_A \cos\theta = 10$

[M1 for horizontal forces & vertical forces]

Alternatively, solve using sine rule / cosine rule for a closed vector triangle



[M1 for correct application]

Solving, $\theta = 75°$ [A1 for angle]

$F_A = 5.18$ N or 5.2 N [A1 for magnitude]

(ii)

As the angle ϕ is increased,

1) The horizontal [leftward] component of F_B increases in magnitude. Thus the horizontal [rightward] component of F_A has to increase in magnitude to ensure equilibrium.

2) The vertical [upward] component of F_B reduces in magnitude, while the [downward] force due to the weight remains constant. Thus the vertical [upward] component of F_A has to increase in magnitude to maintain equilibrium.

[M2 for **both** horizontal and vertical components]

Since **both** horizontal and vertical components of F_A increase, the magnitude of F_A has to increase. [A1]

(b)

Conservation of momentum:

$m(10) + m(0) = mv_A + mv_B$ [C1]

Simplify: $10 = v_A + v_B$

20% of initial total KE was lost

$0.8 [\frac{1}{2} m(10)^2 + \frac{1}{2} m(0)^2] = \frac{1}{2} m(v_A)^2 + \frac{1}{2} m(v_B)^2$ [C1]

Simplify: $80 = v_A^2 + v_B^2$

Solve: $80 = v_A^2 + (10 - v_A)^2$

$v_A = 1.13$ or 8.87

$v_B = 8.87$ or 1.13 [C1 for both solutions if final answer was not identified correctly]

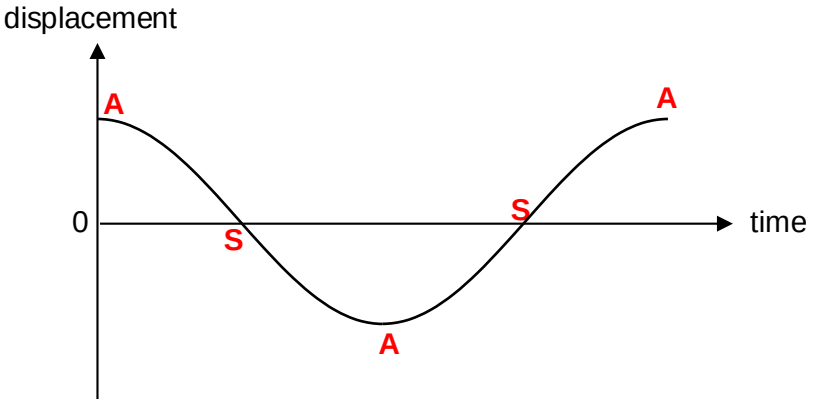
In this case, the only logical possibility is $v_A = 1.13$, $v_B = 8.87$

(both velocities are positive, i.e. A and B are both moving to the right, so v_B must be larger than v_A, i.e. B moves faster than A to the right)
Magnitude = 1.13 m s^{-1}, direction: rightwards [A1]

2 (a) (i)

Simple harmonic motion (S.H.M.) is the oscillatory motion of a particle whose acceleration is always proportional to and opposite in direction from a displacement from an equilibrium point.

(ii)



(b) (i)

loss in GPE = gain in KE

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \times 9.81 \times \left(3.5 \times 10^{-2}\right)}$$ [M1]

$$= 0.83 \text{ m s}^{-1}$$ [A1]

(ii)

$$T - mg = \frac{mv^2}{r}$$

$$T = \frac{mv^2}{r} + mg$$

$$= \frac{0.060(0.83^2)}{1.6} + 0.060(9.81)$$ [M1]

$$= 0.62 \text{ N}$$ [A1]

(c)

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1.6}{9.81}} = 2.54 \text{ s} \qquad \text{[M1]}$$

After striking the obstacle,

$$T_{new} = 2\pi\sqrt{\frac{1.0}{9.81}} = 2.01 \text{ s} \qquad \text{[M1]}$$

Hence,

$$T_{total} = \frac{1}{2}T + \frac{1}{2}T_{new} = \frac{1}{2}(2.54) + \frac{1}{2}(2.01) = 2.28 \text{ s} \qquad \text{[A1]}$$

3 (a)

The electric field strength *E* at a point is the (electric) force per unit charge acting on a small stationary positive charge placed at that point. [B1]

(b) (i)

The value of the net electric field strength along AB is always non-zero. [A1]
If the point charges are of opposite signs, the electric field due to the both charges will always be pointing in the same direction. [M1]
OR
If the point charges are of the same sign, there will be a point along AB where the net E (or net electric force) is zero
as the individual field (or force) experienced by any charge due to the two charges will be opposite in direction. [M1]

(ii)

By counting squares → 530 small squares [M1]
Each small square → (5000/10) × (0.02/10) = 1.0 V [C1]
Therefore the potential difference between A and B is 530 V [A1]
(allow range 500 V – 550 V)

(iii)

Given by question, assume initial KE ≈ 0
By conservation of energy,
gain in kinetic energy = loss in electric potential energy

$$\frac{1}{2}mv^2 - 0 = q\Delta V$$

$$\frac{1}{2}\left(9.11\times10^{-31}\right)v^2 = 1.6\times10^{-19}\left(530\right) \text{ [M1]}$$

$$v = 1.37\times10^{7} \text{ m s}^{-1} \qquad \text{[A1]}$$

4 (a) 1120

4 (b) (i) & **(ii)** Marks given for correct plotted points and best fit line.

(iii)

Using $(2 \times 10^6, 1240)$ and $(22 \times 10^6, 1040)$,

$$B = \text{gradient} = \frac{1240 - 1040}{(2 - 22) \times 10^6} \quad \text{[M1]}$$

$$= -0.000010 \text{ m}^3 \quad \text{[A1]}$$

$$A = \text{vertical intercept} = 1240 - (-0.000010)(2 \times 10^6) \quad \text{[M1]}$$

$$= 1260 \text{ N m} \quad \text{[A1]}$$

(iv)

As pressure increases at constant temperature, volume occupied by a <u>real gas</u> decreases more than proportionally, hence the product <u>pV decreases</u> with increasing pressure.

(v)

$$\frac{\Delta(pV)}{pV} = \frac{\Delta p}{p} + \frac{\Delta V}{V} = 0.05 + 0.03 = 0.08 \quad \text{[M1]}$$

$$\Delta(pV) = 0.08 \times 1160 = 92.8$$

$$\approx 90 \text{ N m} \quad \text{[A1]}$$

(vi)

<u>Horizontal</u> straight line [A1]
At constant temperature T and number of mole = 1, from ideal gas equation, $pV = nRT$ = constant. [M1]

5 (a) (i)

Length of pulse = speed x time = $3.0 \times 10^8 \times 1.0 \times 10^{-10} = 3.0 \times 10^{-2}$ m

(ii)

$\Delta x = 3.0 \times 10^{-2}$ m

(iii)

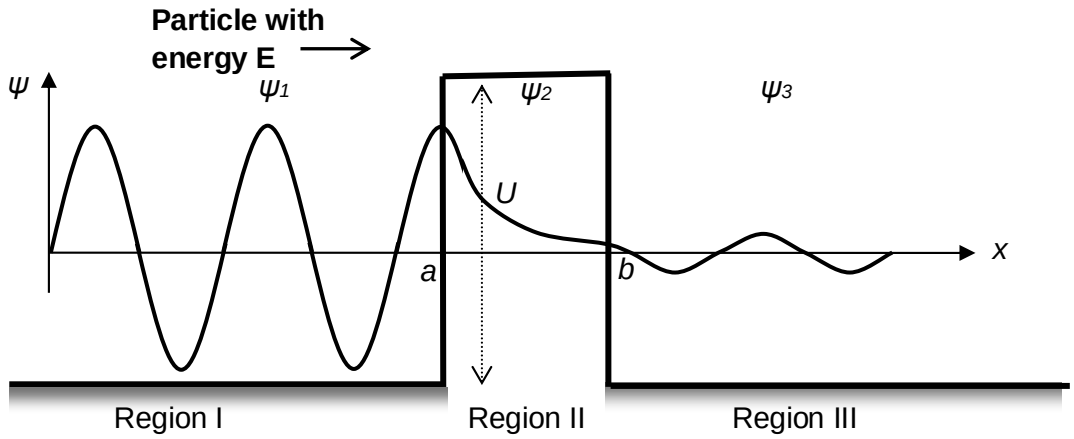
$\Delta x \Delta p \geq h/4\pi$

$$\Delta p = (h/4\pi \Delta x) = \frac{6.63 \times 10^{-34}}{4\pi(3.0 \times 10^{-2})} = 1.76 \times 10^{-33} \text{ kgms}^{-1} \text{ [M1][A1]}$$

(b) (i)

A potential barrier is a region in space where there exists a maximum potential U, higher than that of the energy E of the particle, hence classically preventing the particle to pass through. [B1]

(ii)



Region II: exponentially (decreasing), Ψ at *b* is positive and has non-zero amplitude
Region III: sinusoidal wave function, smaller amplitude compared to Region I, same wavelength as in Region I
[B1 – for correct wave function drawing in region II
B1 – for correct wave function drawing in region III
Minus 1 mark if wave function is not smooth and continuous at a and b]

The square of the amplitude of this function $|\psi|^2$ indicates the probability of finding a particle at a particular position and time. [B1]

The wave function has non zero amplitude on both sides of the barrier. Hence the $|\psi|^2$ is not zero at the region on the right side of the potential barrier. There is a probability that the particle can be found on the other side of the barrier. [B1]

(c)

$$T = \exp(-2kd)$$

where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$

$$= \sqrt{\frac{8\pi^2 (9.11\times10^{-31})(6.0\times1.6\times10^{-19})}{\left(6.63\times10^{-34}\right)^2}}$$

$$= 1.25336\times10^{10}\ \text{m}^{-1} \qquad \text{[M1]}$$

$$T = e^{[-2(1.25336\times10^{10})(d)]}$$

$$0.0001 = 9.0549\times10^{-6}$$

$$d = 3.67\times10^{-10}\text{m} \qquad \text{[A1]}$$

6 (a) (i)

A metastable state is an excited state whose lifetime (time interval until spontaneous emission) is <u>appreciably longer</u> than the typical 10^{-8} second. (10^{-3} s)

(ii)

$E_6 - E_5 = \frac{hc}{\lambda}$

$[-4.026 - (-5.990)] \times 1.60 \times 10^{-19} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda}$ [M1]

$\lambda = 6.33 \times 10^{-7}$ m [A1]

(iii)

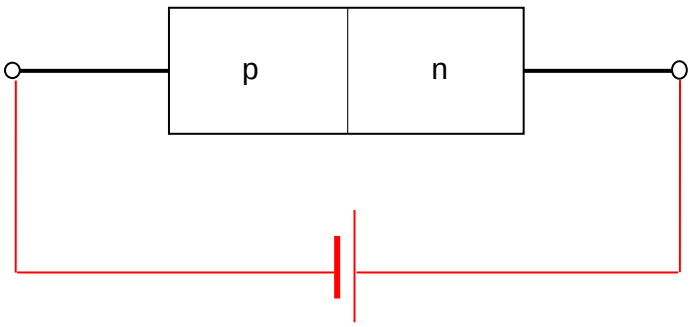
RED

(b) (i)

A p-n junction is formed when a p-type semiconductor is joined to an n-type conduction. At the boundary of the p-n junction, <u>electrons from n-type diffuse into the p-type, while the holes from the p-type diffuse into the n type.</u> [B1]
For the n-type which was originally neutral, a **<u>localised</u>** <u>positive charge is generated</u> due to the loss of electrons. Similarly, the p-type which was originally neutral now gains a localised <u>negative</u> charge as it has lost its holes. [B1]
This results in an <u>electric field</u> being set up at the junction, which opposes and limits further <u>diffusion and recombination</u> of the holes and electrons. [B1]

The <u>region</u> within the electric field that is **<u>depleted</u>** <u>of charge carriers</u> is called the depletion zone. [B1]

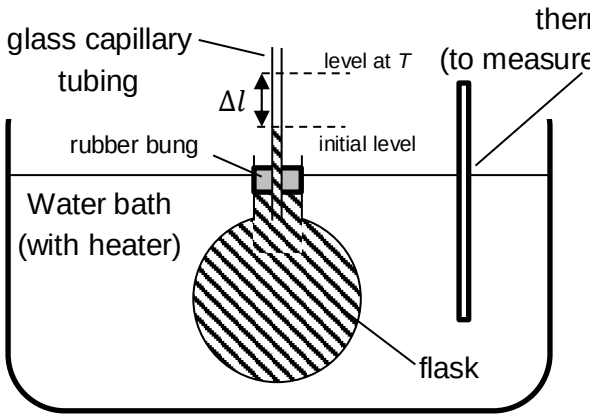
(ii)



7

Basic Procedure	B1 Workable diagram where temperature of water can change (e.g. water bath) and change in volume can be measured. B2 Vary temperature to obtain <u>at least 6 sets of data.</u>	2
Control	C1 Keep mass of water constant by cooling back to initial temperature and ensuring initial capillary level is unchanged, top up if needed. (counter evaporation) C2 Keep external pressure the same (check using pressure gauge.) C3 Monitor the ambient moisture in the air (humidity meter/ hygrometer). C4 Keep external temperature the same (air con room/use thermometer).	1
Methods of measurement	M1 Method to measure initial volume of water $V_i = \frac{mass}{density}$, with using mass balance to measure mass of water in the glass flask / Using a burette / pipette. Measuring flask is not accepted (accuracy). M2 $\Delta\ell$ measured using metre rule, vernier caliper or microscopic scale. M3 Method of measuring temperature, T using thermocouple or thermometer.	3
Analysis	A1 $V_T = \Delta V + V_i$ where $\Delta V = \Delta\ell \times \left(\pi \frac{d^2}{4}\right)$ A2 Plot relevant graph to determine relationship.(V_T vs T)	2
Safety Procedures	S1 Wear gloves when handling hot apparatus. S2 Mention relative safety of the experiment.	1
Reliability of experiment/ Other details	R1 Experiment repeated and results averaged under same conditions (to ensure repeatability). R2 Check zero order for apparatus (e.g mass balance, vernier caliper, thermometer, microscope with scale) – Sensitivity of instrument is important for this experiment! R3 Mark that capillary tube's initial level and final level (first and highest level) to be read with instrument. R4 Ensure container (with initial water) is wiped dry (to exclude extra mass) before weighing. R5 Check that the seal of the glass flask (cover) is tight to prevent evaporation of water. R6 Selected a good range of temperature, e.g. intervals of 10 °C R7 Using a water bath for even heating of flask. R8 Attaching vernier calipers/micrometer to a retort stand to prevent shaking during measurement of Δl. R9 Any other suitable reliability.	3

suggested diagram:



Additional apparatus:

- Mass scale
- Vernier calipers (to measure Δl)
- External thermometer
- External pressure gauge
- External hygrometer

Proposed solutions to JC2 H2 Physics Prelim Paper 3

1 (a)

Average speed = 0.200 / 0.06428 = 3.11139 m s^{-1}
[C1 for value of v]

Max = 0.202 / 0.06427 = 3.14299 m s^{-1}
Min = 0.198 / 0.06429 = 3.07979 m s^{-1}
Δv = (3.14299−3.07979) / 2 = 0.0316 m s^{-1} [C1 for value of Δv]

OR:

$$\frac{\Delta v}{v} = \frac{\Delta d}{d} + \frac{\Delta t}{t} = \frac{0.002}{0.200} + \frac{0.00001}{0.06428} = 0.01016$$

Δv = 0.01016 × 3.11139 = 0.0316 m s^{-1} [C1 for value of Δv]

Final answer = (3.11 ± 0.03) m s^{-1}
[A1 for Δv expressed to 1 s.f., v expressed to 2 d.p. (same number of d.p. as Δv]

(b)

Idea 1: "Average" vs "instantaneous" [B1]
There is an increase in speed as the card is falling through the light gate, so the measured speed is only an average value (based on total distance / total time) and this is not equal to the instantaneous value.

Idea 2: "Speed" vs "velocity" [B1]
The light gate only detects the duration of the obstruction, and thus cannot detect direction of travel (which direction the card is moving).

(c)

Card does not fall straight (e.g. rotates) and this affects the effective length of the card that obstructs the infrared beam.

2 (a) (i)

In polarised transverse wave, the wave oscillates in only one plane that is perpendicular to the direction of wave propagation. [B1]
In unpolarised transverse wave, the wave oscillates in all possible planes perpendicular to direction of wave propagation. [B1]

(ii)

While shining a laser beam through the polariser perpendicularly, rotate the polariser through an axis parallel to the beam. [B1]
The intensity of the laser light exiting the polariser should vary as the polariser is rotated.

(b)

Since the speed of light can be determined from $v = f\lambda$, [B1]
the <u>period / frequency</u> of the wave has to be known. [B1]

(c) (i)

A laser source ensures that the waves from the two slits are <u>coherent</u>, i.e. there is a constant phase difference between the two waves emerging from the slits.

(ii)

$$X = \frac{D\lambda}{a}$$

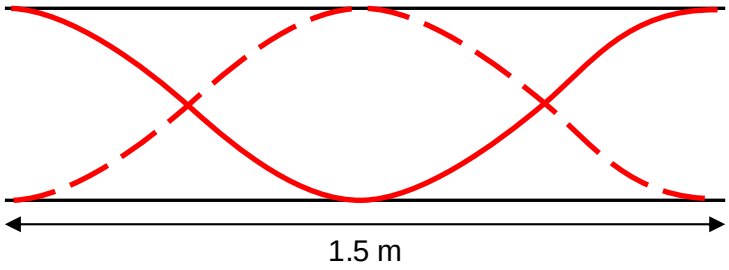
$$5.0 \times 10^{-3} = \frac{6.2\lambda}{0.80 \times 10^{-3}} \quad [M1]$$

$$\lambda = 6.45 \times 10^{-7}\text{ m or } 645\text{ nm} \quad [A1]$$

(iii)

Since intensity of wave propagating away from a point source is inversely proportional to the square of the distance from the point source, [M1]
the intensity will decrease when the screen is moved further. [A1]
Further from the point source, the energy of the wave is spread over a larger surface area and hence intensity decreases.

(d)



[B1]

$$f = \frac{v}{\lambda} = \frac{330}{1.5} = 220\text{ Hz} \quad [B1]$$

3 (a)

$$R_{XY} = R + \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} = R + \frac{R}{3} = 10 + \frac{10}{3} \quad [M1]$$

$$= 13.3\ \Omega \quad [A1]$$

(b) (i)

$$I = \frac{V}{R_{total}} = \frac{3.0}{13.3 + 0.40} \quad \text{[M1]}$$
$$= 0.219 \text{ A} \quad \text{[A1]}$$

(ii)

Since the resistors R_3, R_4 and R_5 are identical and in parallel,

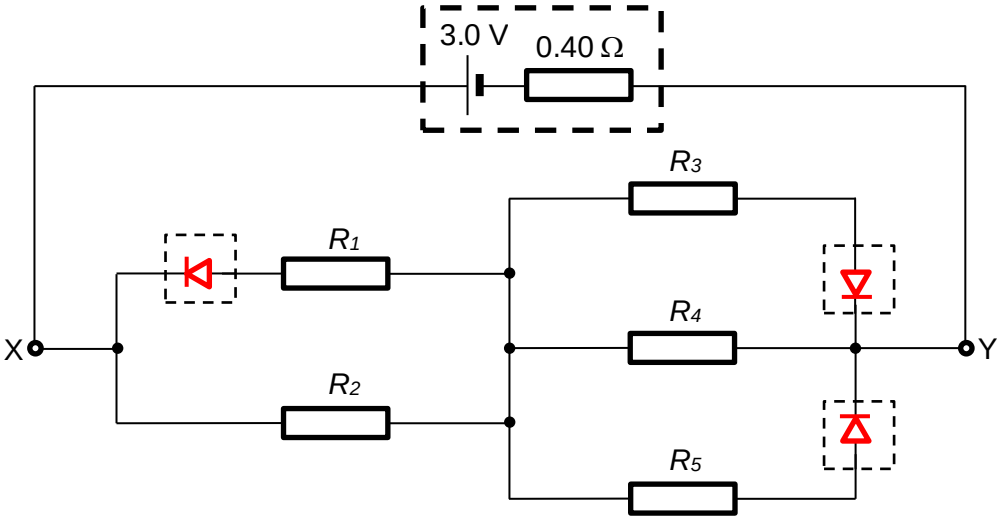
Current through $R_3 = \frac{0.219}{3} = 0.073$ [C1]

$P = I^2 R_3 = (0.073)^2 (10)$
$= 0.0532$ W [A1]

Alternatively; use potential divider to find p.d. across R_3; use $P = \frac{V^2}{R}$

.

(c)



[M1] Correct orientation (Not accepting just arrows, students should at least draw the triangle to indicate direction of allowed current flow)
[A1] Correct symbol ( , circle optional, with lines to connect to the rest of the circuit)

(d)

A small internal electric field across the depletion region of a P-N junction prevents the movement of majority charge carriers through the junction

The small forward biased potential difference across the terminals reduces the internal electric field and depletion region [B1] and allow the (majority) charge carriers to move [B1] and constitutes to a current flowing through the diode.

4 (a)

Emission line spectrum consists of discrete bright coloured lines on a dark background. [B1]
Absorption spectrum consists of dark lines against a continuous spectrum of white light. [B1]

(b)

Summary of important points (3 main points):
1) Thermal excitation / electrical discharge / white light source which causes the atoms of the gas to be excited [B1]

Gases such as hydrogen or neon can be placed in a discharge tube at low pressure. A voltage (several kilo-volts) is applied between metal electrodes in the tube which is large enough to produce an electric current in the gas. The gas becomes excited by the collisions with the electrons passing through the tube, from cathode to anode of the discharge tube.

2) Photons emitted due to de-excitation of atoms (from a higher energy level to a lower energy level) [B1]

The excited gas atoms are unstable. When the gas atoms undergoes a transition to a lower energy level, the excess energy is emitted as electromagnetic radiation (photon) with a specific frequency.

3) Each discrete bright line in the spectrum corresponds to one particular photon energy of specific frequency or wavelength. [B1]

OR

The frequency f of the emission line is dependent on the difference between the high and low energy levels, $\Delta E = hf$. Due to the discrete energy levels, only certain high-to-low energy level transitions are possible within the atom, therefore only certain frequency lines are present in the spectrum. [B1]

(c)

No two gases/ elements give the same exact line spectrum. [B1]
Hence by comparing the line spectrum of the given sample with that of known elements, we can identify the elements in that sample. [B1]

(d) (i)

13.6 eV or 2.176×10^{-18} J [B1]

(ii)

Kinetic energy of electrons = $2.00 \times 10^{-18} / 1.60 \times 10^{-19} = 12.5$ eV
hence the highest state that the atom can be excited to is n=3. [B1]

Hence only the following transitions are observed
From n =3 to n=2
From n =2 to n=1
From n =3 to n=1
[B1 for all three correct transitions – no mark will be given if excitation instead of de-excitations were mentioned.]

(iii)

The energy of the photon does not match exactly any of the energies required for the atom to get excited from the ground state to higher excited state hence the photons incident will not be absorbed by the atom. [M1]
No emission lines will be observed or no transition occurs (atoms still remain at ground state). [A1]

5 (a) (i)

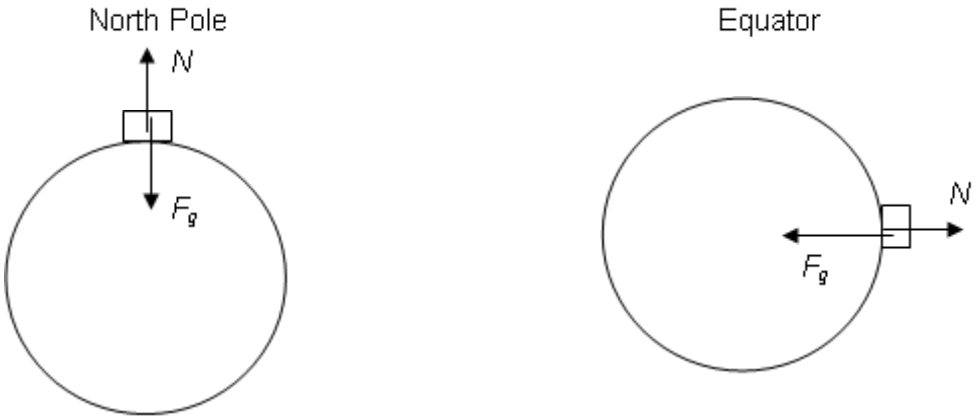
Newton's Law of Universal Gravitation states that any two point masses attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

(ii)

Gravitational forces are only significant when the masses involved are massive. This is because of the magnitude of Newton's universal gravitational constant, <u>*G* whose magnitude is very small</u>. [B1]

Hence atoms and molecules whose masses are very small would result in insignificant magnitude of gravitational forces.

(iii)



Free Body diagram (include N and F_g) [B1]
At the pole, it is not rotating.
At the equator, it is rotating with an angular velocity being constant, centripetal acceleration ($a = r\omega$) and hence centripetal force ($F = ma$) are not constant.
Centripetal acceleration/force is maximum at the equator and is zero at the poles.
[B1]
Fg – N = Fc
N = Fg - Fc
Fg is constant assuming that earth is spherical in shape.
Hence at the equator the weight measured (N) will be smaller compared to the poles due to a larger centripetal acceleration/force. [B1]

(b) (i)

The satellite is travelling with constant speed but its direction is changing, hence it experiences acceleration so it is not in equilibrium.
Or
The satellite experience a net force (centripetal force) hence it is not in equilibrium
[B1]

(ii)

Gravitational force provides for centripetal force

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}} \qquad \text{[M1]}$$

$$E_K = \frac{1}{2}mv^2$$

$$= \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2$$

$$= \frac{1}{2}\frac{GMm}{r} \qquad \text{[A1]}$$

(iii)

$E_P = -\dfrac{GMm}{R}$, hence $E_P \propto \dfrac{1}{R}$

$\dfrac{E_P}{E_{Psurface}} = \dfrac{R_{surface}}{R}$

$E_P = \dfrac{6.4\times10^6}{4.3\times10^7} \times -9.6\times10^{10}$ [M1]

$= -1.43\times10^{10}$ J

From (b)(i): $E_K = +\dfrac{1}{2}\left(1.43\times10^{10}\right)$ [M1]

Energy supplied + $E_{Psurface} = E_{Porbit} + E_{Korbit}$

Energy supplied = $\left(E_{Porbit} - E_{Psurface}\right) + E_{Korbit}$

$= \left(-1.43\times10^{10} + 9.6\times10^{10}\right) + \dfrac{1}{2}\left(1.43\times10^{10}\right)$ [M1]

$= 8.9\times10^{10}$ J [A1]

(iv)

If the satellite is launched at the equator, it will have an initial kinetic energy since it has an initial (angular) speed at the equator. [M1]

(v)

Height of the satellite will decrease as friction will cause the total energy of the satellite to decrease. $E_{total} = -\dfrac{GMm}{2r}$, as total energy will be more negative, hence height will decrease. [B1]

Speed of the satellite will increase as $E_K = \dfrac{GMm}{2r}$, so with a decrease in height, kinetic energy increase, hence speed increase. [B1]

(c) (i)

$\dfrac{GMm}{R^2} = mR\omega^2 = mR\left(\dfrac{2\pi}{T}\right)^2$

$\dfrac{R^3}{T^2} = \dfrac{GM}{4\pi^2}$ [M1]

$=$ constant [A0]

(ii)

orbital period of geostationary satellite $= 24 \times 60 \times 60 = 86400$ s [M1]

$$\frac{R_{0.1R_E}^{\ 3}}{T_{0.1R_E}^{\ 2}} = \frac{R_{geo}^{\ 3}}{T_{geo}^{\ 2}}$$

$$\frac{(1.1R_E)^3}{5100^2} = \frac{(R_{\text{geo}})^3}{86400^2}$$

$$R_{\text{geo}} = 7.3R_E$$

$\therefore$ orbital radius of geostationary satellite $= 7.3R_E$ [A1]

(iii)

Advantages:

1. As they remain stationary above the same point on Earth, they are ideal for use as communication satellites as it requires no tracking to receive its downlink signal. This is why there is no need to keep adjusting the satellite dish to receive TV signal from a particular geostationary satellite.
2. As geostationary satellites are positioned at such a high altitude they can view the whole earth disc below them, rather than a small subsection, and they can scan the same area very frequently. They are ideal for meteorological applications and remote imaging.

Disadvantages:

1. Since they are positioned at such a high altitude, the spatial resolution (i.e. the amount of detail shown) of their images tends to be not as good.
2. Since they are positioned above the equator they cannot see the north or south poles and are of limited use for latitudes greater than 60 -70 degrees north or south. The further from the equator the lower, the spatial resolution of each pixel and the greater the possibility of being hidden by the earth's curvature.

6 (a) (i)

Faraday's Law of Electromagnetic Induction states that
the magnitude of 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]

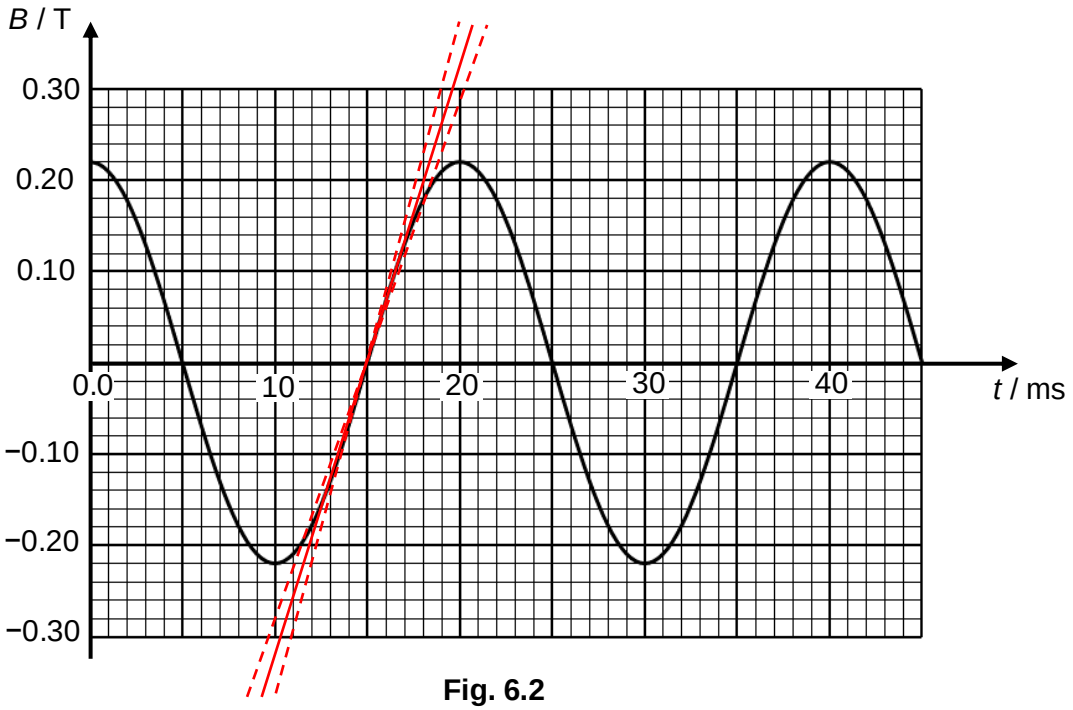


Fig. 6.2

Must draw tangent line

(ii)

Since Faraday's law state that $\varepsilon = -\frac{d\phi}{dt}$, taking the gradient at t = 15 s (tangent drawn correctly) [M1]

$$\varepsilon = \left| -\frac{\phi_2 - \phi_1}{t_2 - t_1} \right| = NA \left| -\frac{B_2 - B_1}{t_2 - t_1} \right|$$

$$= 500 \times 0.010 \times \frac{\left| [0.26 - (-0.26)] \right|}{(19 - 11) \times 10^{-3}} \quad \text{[M1]}$$

$$= 325 \text{ V} \quad \text{[A1]}$$

accept range between 280 and 375 (dotted lines)

(iii)

shape: Positive sine curve [B1]
labels: correct period and max/min emf [B1]

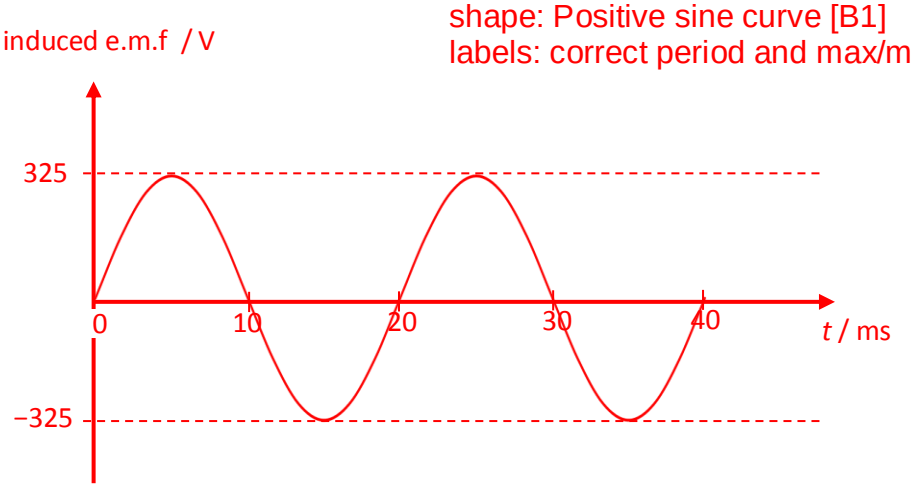


Fig. 6.2

(iv)

$$I_{peak,secondary} = \frac{V_{peak,secondary}}{R} = \frac{325}{8} = 40.625 \text{ A} \quad [M1]$$

$$I_{rms,secondary} = \frac{I_{peak,secondary}}{\sqrt{2}}$$

$$= \frac{1}{\sqrt{2}}(40.625) \quad [M1]$$

$$= 28.7 \text{ A} \quad [A1]$$

(v)

Using value in (ii)

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$V_P = V_S \frac{N_P}{N_S} = 325 \times \frac{3200}{500} \quad [M1]$$

$$= 2080 \text{ V} \quad [A1]$$

(vi)

The peak e.m.f decreases.
Without the soft iron rod, <u>less of the magnetic flux from the primary coil links to the secondary coil</u>. [B1]
The <u>rate of change of magnetic flux linkage in the secondary coil decreases [B1]</u>,
Thus by Faraday's law, <u>the peak e.m.f decreases</u>. [A0]

(b) (i)

Magnetic flux density is <u>the force acting per unit current per unit length on a conductor placed at right angles to a magnetic field</u>. [B1]

(ii)

Linear velocity for circular motion is $v_{\perp} = v\sin\theta$

Magnetic field perpendicular to charge motion is $B_{\perp} = B\sin\theta$ [M1]

$F_{net} = ma$

$F_{magnetic} = \frac{mv^2}{r}$

$B_{\perp}qv = \frac{mv_{\perp}^{\ 2}}{r}$ [M1]

$r = \frac{mv_{\perp}^{\ 2}}{B_{\perp}q} = \frac{mv\sin\theta}{Bq}$

(iii)

$\omega = \frac{v_{\perp}}{r} = \frac{Bq}{m}$ $\left(\text{from } r = \frac{mv_{\perp}}{Bq}\right)$ [M1: invoking $v_{\perp} = r\omega$]

$T = \frac{2\pi m}{Bq}$ [M1: invoking $\omega = \frac{2\pi}{T}$]

(iv)

The magnetic force experienced is always perpendicular to the velocity of the electron. [B1]

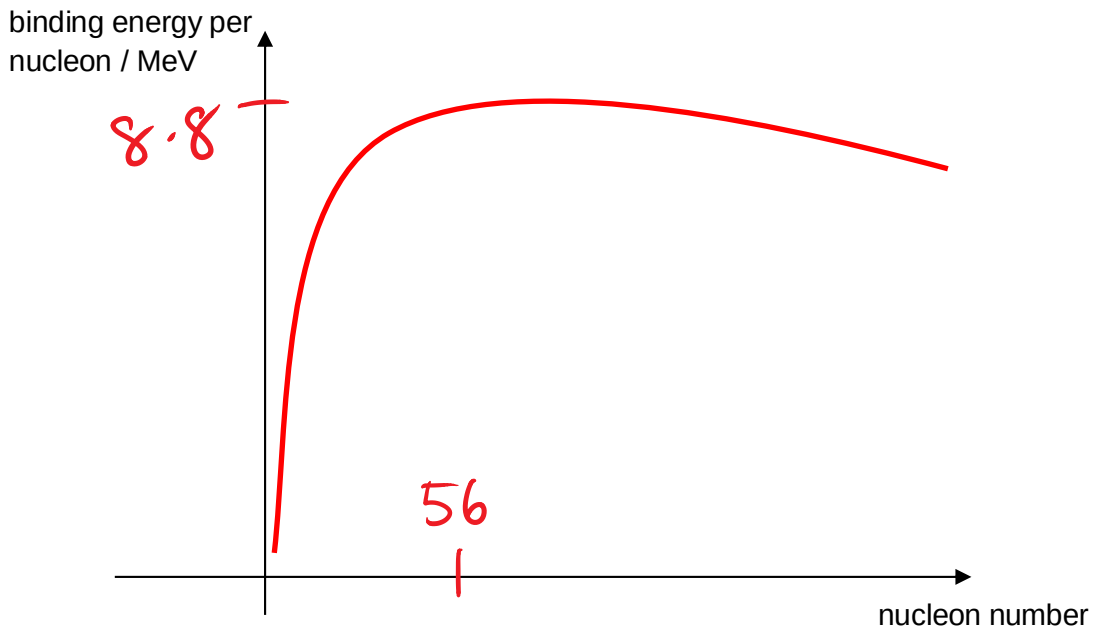
7(a) **(i)** .

mass defect = [3 (1.008664) +3 (1.007276) – 6.015122] (1.66 x 10^{-27})
= 5.427868 x 10^{-29} kg [C1]

binding energy per nucleon $= \frac{5.427868\times10^{-29}\times\left(3.0\times10^{8}\right)^2}{6}$ [M1]

= 8.14 x 10^{-13} J [A1]

(ii)



1 mark for correct shape and label for Fe-56, 8.8 MeV must be given

(iii)

Energy required
= [2.014102 + 3.016049 – (4.002602 + 1.008664)] x 1.66 x 10^{-27} x $(3.0 \times 10^8)^2$ [M1]
= 2.821419 x 10^{-12} J

= 17.6 MeV
[A1]

(iv)

Fusion is a difficult process to achieve because of the <u>strong electrical repulsion between the nuclei when they are close to each other</u>. [B1] At extremely high temperatures (in excess of 10^8K) the nuclei have <u>enough kinetic energy to overcome the repulsion</u>. [B1]

(b) (i)

1.

Radioactive decay is the <u>spontaneous emission of particles</u> (α or β particles) <u>and/or</u> <u>radiation</u> (γ ray) [B1] from an <u>unstable nucleus</u> so that it becomes <u>more stable</u>. [B1]

2.

The rate of decay of the nuclei is <u>not affected by external environmental conditions</u> [B1] (e.g. physical factors such as pressure, temperature, magnetic and electric fields or chemical conditions)

3.

In a random process, it is impossible to predict *which nucleus* will decay next. There is a constant probability that a nucleus will decay in any fixed period of time. [B1]

(ii)

from the graph, 2 $t_{1/2}$ = 12 hr, therefore $t_{1/2}$ = 6.0 hr [A1]

(iii)

$$A_{30hr} = \left(\frac{1}{2}\right)^5 4000 = 125 \text{ Bq} \qquad [M1]$$

$$A = 125 = \lambda N = \frac{\ln 2}{6 \times 60 \times 60} N \qquad [M1]$$

Therefore, N = 3895276.61 nuclei

mass = N x m_{nuclei} = 3895276.61 x 98.9063 x 1.66 x 10^{-27}
[M1]
= 6.39543879 x 10^{-19} kg = 6.40 x 10^{-19} kg (3sf) [A1]

(iv)

Technetium-99* has a half-life of six hours which is long enough for medical imaging [B1] yet short enough to minimise the radiation dose to the patient. [alt B1] ---- maximum 1 mark

The product has a very long half-life, much longer than average life expectancies, hence, it is unlikely that it will decay to form beta particles that would do damage to the cells in the body in the patient's lifetime. [B1]---- longer half-live, The product has a long half life and hence will have a much lower activity, making the product relatively safe [alt B1] ---- maximum 1 mark

(v)

gamma is least ionising and therefore less damaging to cells than alpha. [B1]

H

NATIONAL JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9646/01

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

31 August 2016
1 hour 15 minutes

INSTRUCTIONS ON SHADING OF REGISTRATION NUMBER



Shade the index number in a 5 digit format (12345) on the Answer Sheet.

OAS index number is in 5-digit format.

5 digit format: **2nd digit** and the **last four digits** of the Reg Number.

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.

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 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.

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}
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,	$s = ut + \frac{1}{2}at^2$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
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* $v = \pm\omega\sqrt{x_0^{\,2} - x^2}$
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,	$x = x_0 \sin \omega t$
Transmission coefficient	$T = ex\ p(-2kd)$ *Where* $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

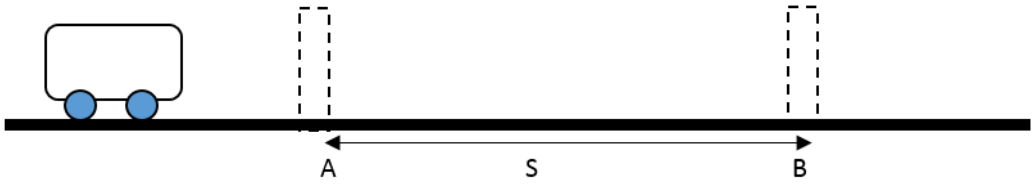
1. The volume of liquid flowing per second is called the volume flowrate Q and has the unit $m^3\ s^{-1}$. The flowrate through a hypodermic needle during an injection can be estimated with the following equation:

$$Q = \frac{\pi R^n (P_2 - P_1)}{8\eta L}$$

The length and radius of the needle are L and R, respectively. The pressure at opposite ends of the needle are P_2 and P_1. The viscosity of the liquid is given by η which has the unit $kg\ m^{-1}\ s^{-1}$. The value of n is

A 2 **B** 3 **C** 4 **D** 8

2. In an experiment to find the constant acceleration of a toy car, the speed of the toy car was captured using speed meters placed at 2 different locations, **A** and **B** respectively.



The distance between **A** and **B** is measured as *S*.

Distance S = 1.400 m ± 0.002 m

The manufacturer for the speed meter quoted an uncertainty of 1 % for their instrument.

Speed measured at A = 2.50 m s^{-1}

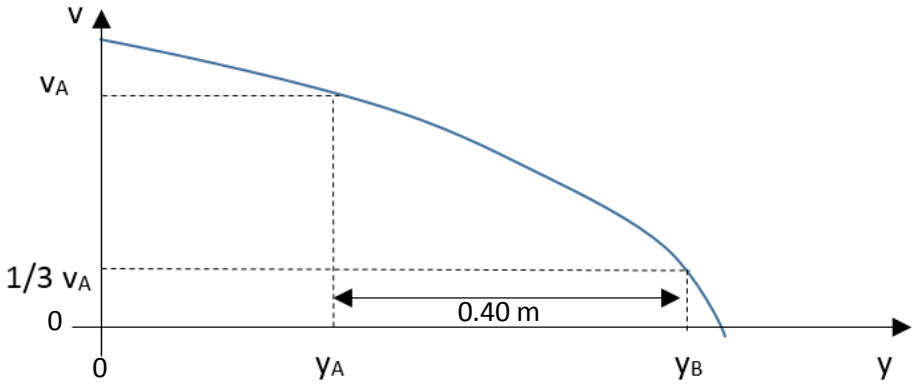
Speed measured at B = 4.65 m s^{-1}

The correct acceleration of the toy car is

A (5.49 ± 0.04) m s^{-2} **B** (5.50 ± 0.04) m s^{-2}

C (5.5 ± 0.4) m s^{-2} **D** (5.5 ± 0.2) m s^{-2}

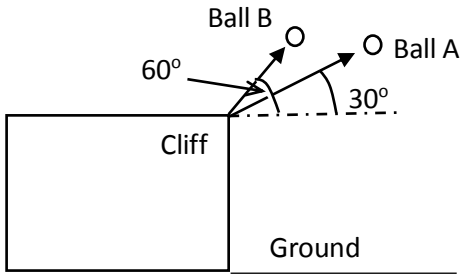
3. The figure below shows the speed v versus vertical height y of a ball tossed directly upward. The speed at height y_A is v_A. The speed at height y_B is 1/3 v_A. What is the speed v_A?



A 2.10 m s^{-1} **B** 2.97 m s^{-1}

C 6.98 m s^{-1} **D** 9.40 m s^{-1}

4. Two similar balls **A** and **B** were fired at different angles but with the same vertical velocity from the edge of a cliff. Which of the following statements is false?



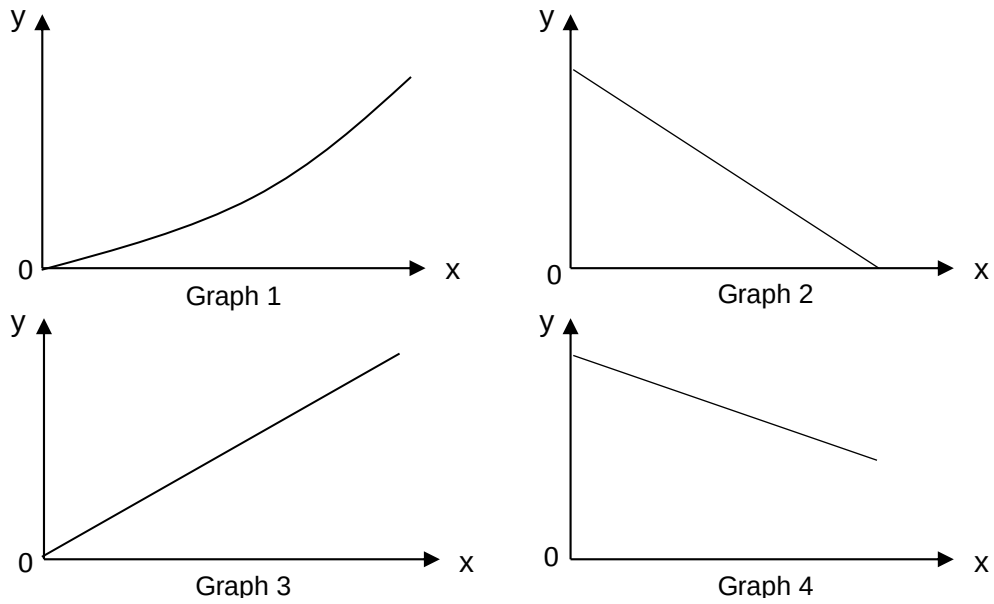
A Both balls will hit the ground at the same time.

B The change in momentum of both balls are the same.

C The ratio of the horizontal velocity of ball **A** to the horizontal velocity of ball **B** is a constant value of $1/\sqrt{3}$.

D The kinetic energy of ball **A**, just before impact with the ground**,** is greater than ball **B**.

5. An object is projected with a certain velocity at an angle from a flat surface. Which of the following graphs correctly shows the variation of the horizontal displacement with time, and the variation of the kinetic energy with vertical displacement of the object?



	Horizontal displacement vs time	Kinetic energy vs vertical displacement
A	Graph 1	Graph 2
B	Graph 1	Graph 4
C	Graph 3	Graph 2
D	Graph 3	Graph 4

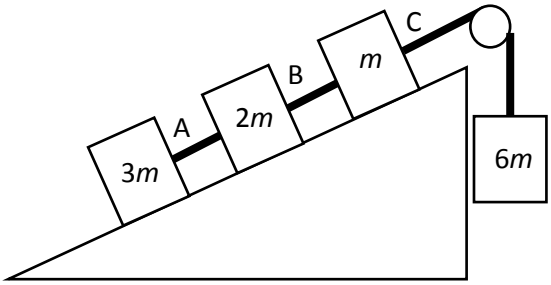
6. Consider two laboratory carts of different masses but both possess identical kinetic energy. Which of the following statements must be correct?

(1) The one with the greatest mass has the greatest momentum
(2) The same impulse was required to accelerate each cart from rest
(3) Both can do the same amount of work as they come to a stop
(4) The same amount of force was required to accelerate each cart from rest

A (1), (4) **B** (2), (3)

C (3), (4) **D** (1), (3)

7. Three blocks of masses 3*m*, 2*m* and *m* are connected to strings **A**, **B** and **C** as shown below. The blocks are placed on a smooth slope surface and attached to a block of mass 6*m* by string **C**. Assuming that the pulley is smooth, which string must be the strongest in order not to break when the block of mass 6*m* is released?



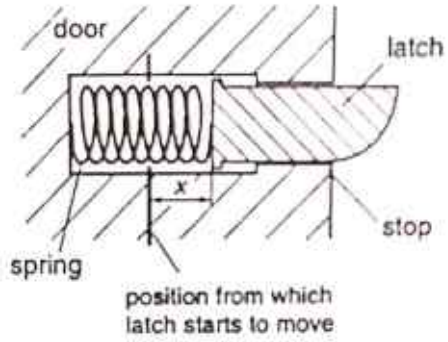
A A

B B

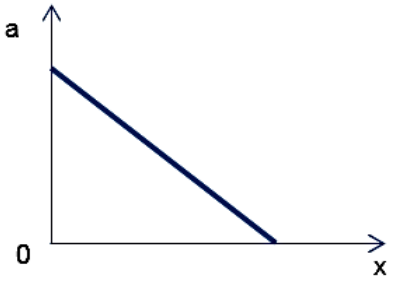
C C

D They must all be the same strength.

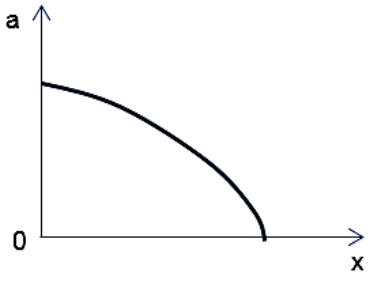
8. A door is fitted with a spring-operated latch as shown. When the latch is pushed in, the spring becomes compressed but remains within its elastic limit. The latch is suddenly released.
Which graph best shows how the acceleration ***a*** of the latch varies with distance ***x*** it moves before it stopped? Ignore friction.



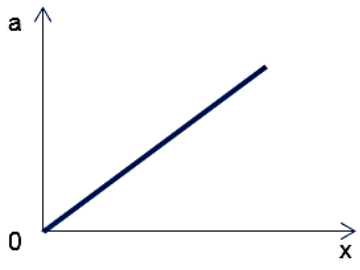
A



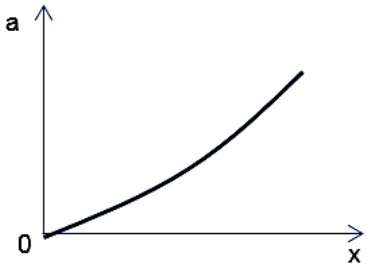
B



C



D



9. A child drinks a liquid of density ρ through a vertical straw. Atmospheric pressure is p_o and the child is capable of lowering the pressure at the top of the straw by 10 %. What is the maximum length of straw above the liquid that would enable the child to drink the liquid?

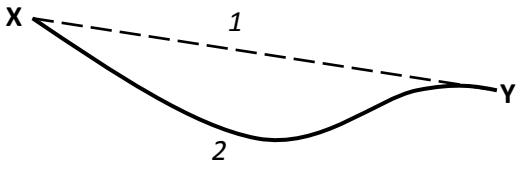
A $\frac{p_O}{10\rho g}$

B $\frac{p_O}{\rho g}$

C $\frac{9p_O}{10\rho g}$

D $\frac{10p_O}{\rho g}$

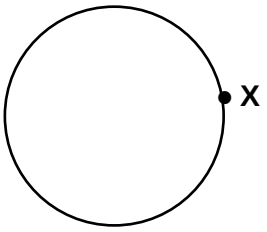
10. Two identical balls were released simultaneously from rest at **X** and made their way to **Y** along two different tracks on the same vertical plane as shown below. Ball 1 travels along a straight down-slope track while ball 2 travels along a curve down-slope followed by an up-slope track. Ball 2 reaches **Y** first.



Neglecting all resistive forces, what can be said of the final energy and the average rate of energy conversion for the two balls?

	Final total energy of	Higher average rate of energy conversion
A	Both balls are the same	Ball 2
B	Ball 2 is higher	Ball 1
C	Ball 2 is higher	Ball 2
D	Both balls are the same	Ball 1

11. A model car moves in a circular path of radius 0.80 m at an angular speed of $2\pi/3$ rad s^{-1}.

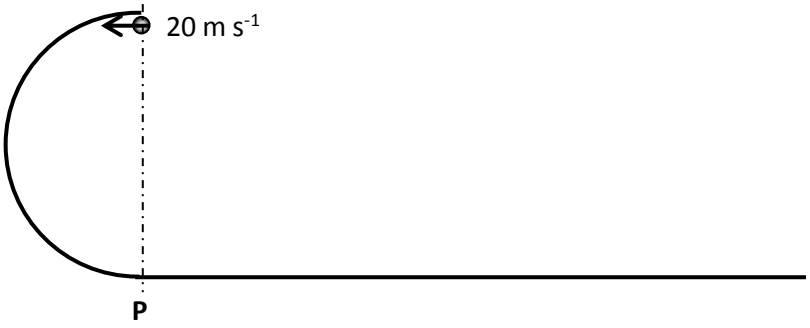


What is its distance travelled from a point **X**, 6.0 s after passing **X**?

A zero **B** 0.8π m

C 1.6π m **D** 3.2π m

12. A rigid track in a plane vertical to the ground consists of a semi-circular section of diameter 5.0 m and a straight horizontal section. A small object with a mass of 100 g is projected horizontally into the track at the top with a speed of 20 m s^{-1}. The track exerts an average resistive force of 1.0 N to the object. Point **P** is vertically below the projection point.



Assuming that the object always stays in contact with the track, calculate the distance from point **P** where the object comes to rest.

A 9.2 m **B** 17.1 m

C 19.9 m **D** 24.9 m

13. A roundabout in a playground rotates uniformly about is vertical axis.

What is the minimum period of rotation of the roundabout, for a girl of 40 kg to stay on safely, if she was standing 2.0 m from the vertical axis as the roundabout rotates?

Frictional force on girl due to the surface of roundabout, $F = 1.16\ W$, where W is the weight of the girl.

A 2.2 1 s **B** 2.38 s **C** 2.63 s **D** 6.94 s

14. The radius of the Earth is R and X is a point $4R$ from the surface of the Earth. When a stationary object of mass m falls from X towards the Earth, which of the following statement is false? The mass of Earth is M.

A The speed of impact is $\sqrt{\frac{8GM}{5R}}$

B The work done by the gravitational field is $\frac{0.8\ GMm}{R}$.

C The change in the magnitude of gravitational field strength is $\frac{0.96\ GM}{R^2}$.

D The change in gravitational potential is $\frac{0.8\ GM}{R}$.

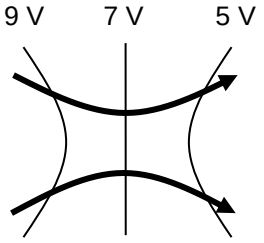
15. A satellite is put in circular orbit about Earth with a radius equal to half of the radius of the Moon's orbit. Given that the period of revolution of the Moon is T, what is the period of the satellite's revolution in terms of T?

A $\frac{T}{8}$ **B** $\frac{T}{2\sqrt{2}}$

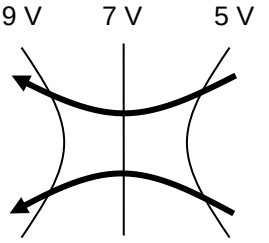
C $\frac{T}{2}$ **D** $2\sqrt{2}\ T$

16. In the diagrams, the thin lines show equipotential lines and the bold arrows show the electric field lines and their directions. Which set of equipotential lines and field lines is possible?

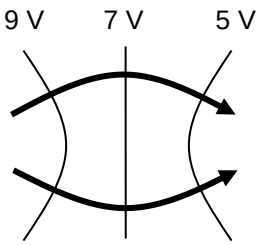
A



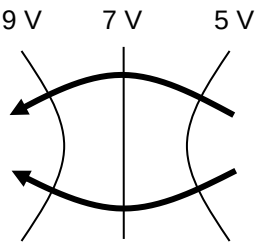
B



C



D



17. A jet of steam at 100 °C is directed into a hole in a large block of ice of 0 °C. After the steam has been switched off, the condensed steam and the melted ice are both at 0 °C. The mass of water collected in the hole is 206 g. Calculate the mass of ice melted.
Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
Specific latent heat of vaporisation of water = 2260 kJ kg^{-1}
Specific latent heat of fusion of water = 330 kJ kg^{-1}

A 22.5 g **B** 26.2 g

C 179.8 g **D** 183.5 g

18. 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 1/5 **B** 1/3 **C** 3/5 **D** 1

19. A particle oscillates with simple harmonic motion. Which of the following statements about the acceleration of the oscillating particle is true?

.

A It is least when the speed is greatest.

B It is always in the opposite direction to its velocity.

C It is proportional to the frequency of the wave.

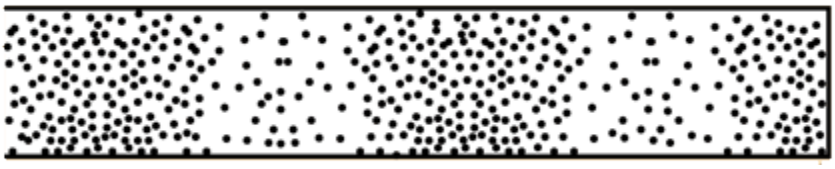
D It decreases as the potential energy increases.

20. A loudspeaker emits a sound wave of amplitude *A* and intensity *I*. After some time, the intensity increased by 8.00 %. The corresponding change in amplitude is

A 3.92 % **B** 16.6 %

C 104 % **D** 108 %

21. The diagram below shows the positions of the air particles for an open-closed tube at the instant when time t = 0 s.



Which of the following statements is NOT correct?

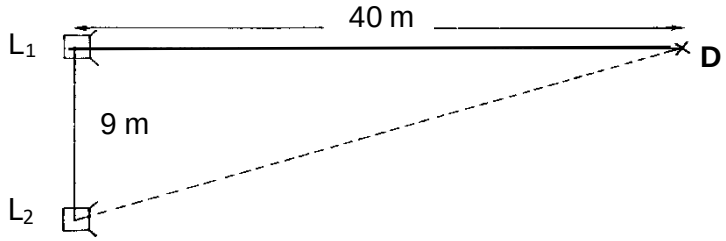
A At the instant t = 0 s, the air pressure variation is maximum but the air velocity is zero at the closed end.

B There will always be more than 2 complete wavelengths in the tube at any instant in time.

C At the instant $t = T/4$, the air pressure variation is zero but the air acceleration is maximum at the open end.

D The frequency of the air particles is 9 times the value of the fundamental frequency.

22. Two loudspeakers L_1 and L_2, driven by a common oscillator and amplifier, are set up as shown. As the frequency of the oscillator increases from zero, the detector at **D** recorded a series of maximum and minimum signals. At what frequency is the first **minimum** observed?
(Speed of sound = 330 m s^{-1})

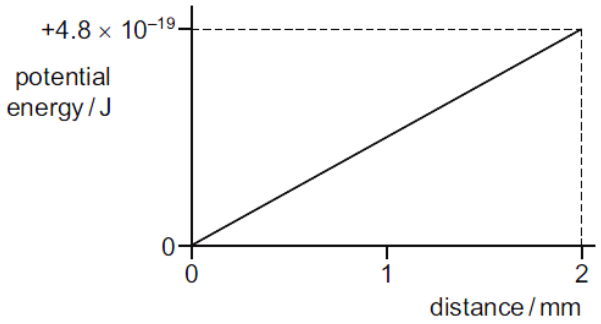


A 165 Hz **B** 330 Hz **C** 495 Hz **D** 660 Hz

23. A beam of light of wavelength λ is incident normally on a diffraction grating. The angular separation between the two second order maxima is θ. The resolution of the grating is d. Which row corresponds to the correct values of λ, θ and d?

	λ	θ	d
A	710 nm	60°	3.5 x 10^5 lines per metre
B	710 nm	30°	1.5 x 10^5 lines per metre
C	420 nm	60°	3.5 x 10^5 lines per metre
D	420 nm	30°	1.5 x 10^5 lines per metre

24. Two parallel plates **R** and **S** are 2.0 mm apart in a vacuum. An electron moves along a straight line in the electric field between the plates. The graph shows how the potential energy of the electron varies with its distance from plate **R**.



Which of the following statements is false?

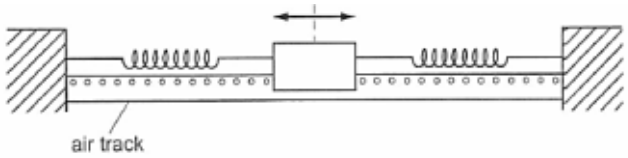
A The electric field between **R** and **S** is uniform.

B The electric field strength is 3000 N C^{-1}.

C The force on the electron is constant.

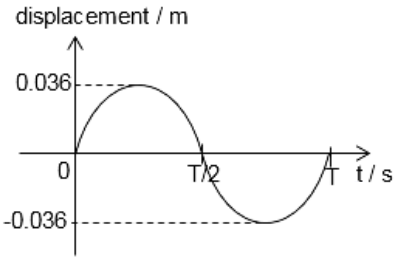
D The magnitude of the potential difference between **R** and **S** is 3.0 V.

25. A linear air track vehicle of mass 2.0 kg held centrally on an air track by two springs makes simple harmonic oscillations.

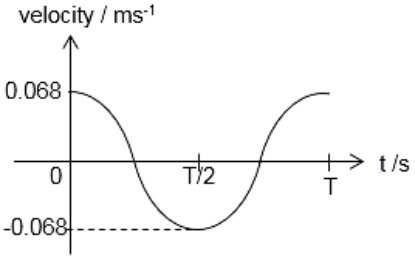


When its displacement from equilibrium is 0.020 m, it speed is 0.030 m s^{-1}.
When its displacement from equilibrium is 0.030 m, it speed is 0.020 m s^{-1}.
Assuming at t = 0, the vehicle is at the equilibrium position, which one of the following graph must be wrong because it does not correspond with the others?

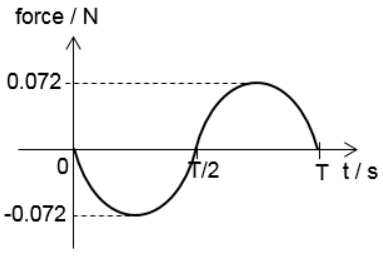
A



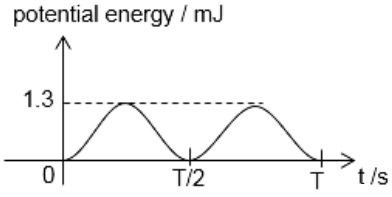
B



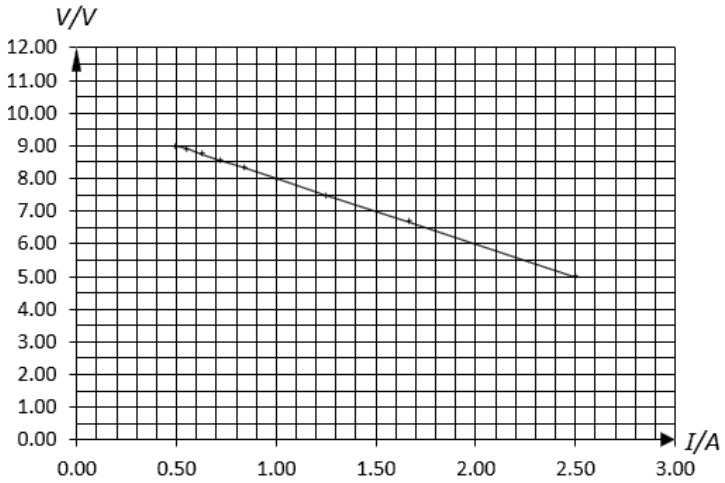
C

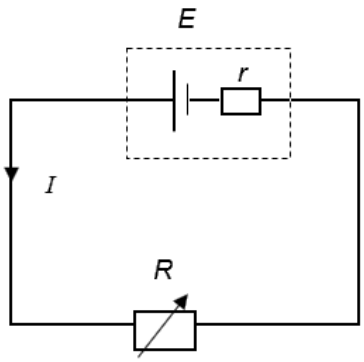


D



26. A battery of e.m.f. *E,* with internal resistance *r*, is connected in series with a variable resistor *R* (refer to circuit diagram). The figure below shows the variation of the terminal p.d *V* to the current I in the circuit as *R* is varied. Which of the following statement is false?





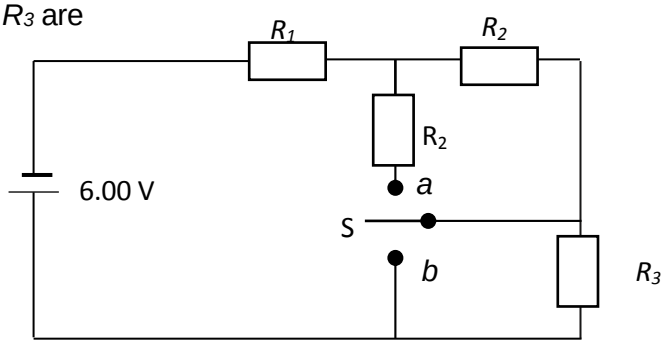
A The internal resistance *r* is 2.0 Ω.

B When the current in the circuit is 2.50 A, the resistor *R* is 4.0 Ω .

C The e.m.f of the battery *E* is 10 V.

D When the *R* = 50 Ω, the power dissipated in the resistor *R* is 1.85 W.

27. A 6.00 V battery supplies current to the circuit shown in the figure below. When the double-throw switch **S** is open as shown in the figure, the current in the battery is 1.00 mA.
When the switch is closed in position *a*, the current in the battery is 1.20 mA. When the switch is closed in the position *b*, the current in the battery is 2.00 mA. The resistances of R_1, R_2, R_3 are



	R_1/Ω	R_2/Ω	R_3/Ω
A	2000	1000	3000
B	1000	2000	3000
C	3000	1000	2000
D	3000	2000	1000

28. A small plastic sphere carrying a positive charge is maintained at a constant height by the action of an upward vertical electric field.

A uniform magnetic field is applied in the same direction as the electric field.

What does the sphere do?

A Move downwards in a spiral path.

B Move in a horizontal circle.

C Move upwards in a spiral path.

D Remain stationary.

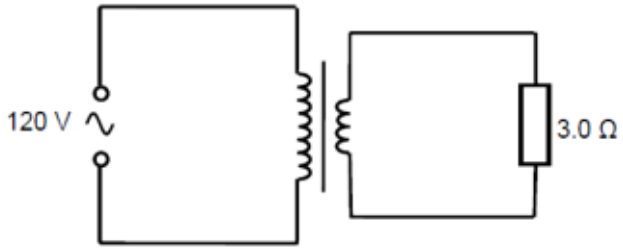
29. A mains electricity supply has a root-mean-square voltage of 240 V and a peak voltage of 340 V. When connected to this supply, a heater dissipates energy at a rate of 1000 W. The heater is then connected to a 340 V d.c. supply and its resistance remains the same.

At what rate does the heater now dissipate energy?

A 1000 W **B** 1400 W

C 2000 W **D** 2800 W

30. A transformer is use to step down 120 V a.c. voltage supply to a 3.0 Ω resistive load. The ratio of the secondary turns to the primary turns is 1:20. What is the current in the primary coil?



A 40 A **B** 6.0 A **C** 2.0 A **D** 0.10 A

31. Diagram 1 shows an aluminium rod, moving at right angles to a uniform magnetic field. Diagram 2 shows the variation with time *t* of the distance *s* from **O**.

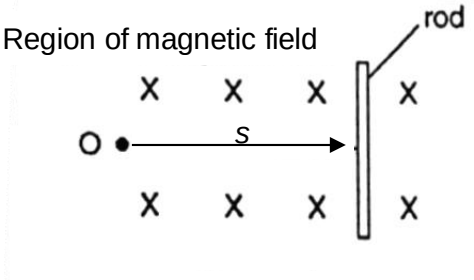


Diagram 1

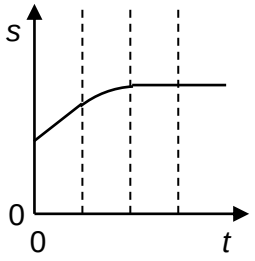
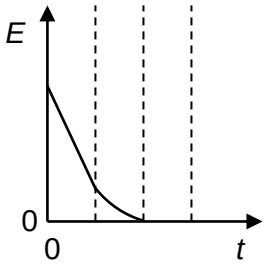


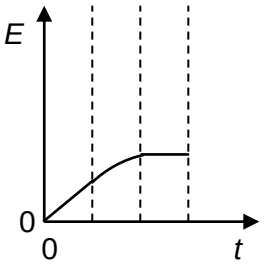
Diagram 2

Which graph best shows the variation with time *t* of the e.m.f. *E* induced in the rod?

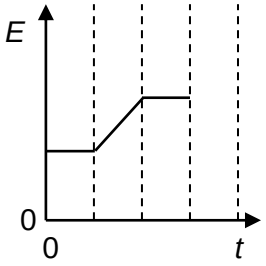
A



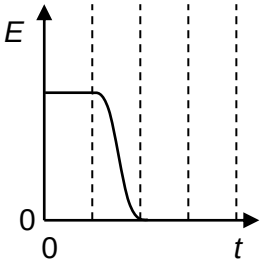
B



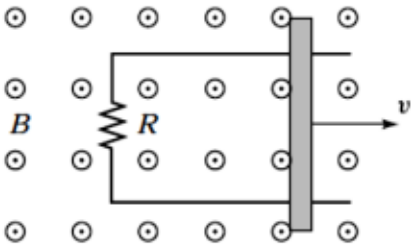
C



D



32. An external force F is exerted on a conducting bar which moves to the right with constant velocity v in a uniform magnetic field B that points out of the page. The conducting rod has negligible internal resistance.



Which of the following statements is most likely correct?

A The current in the conducting bar flows from higher potential to lower potential.

B F must be increasing to ensure that the conducting bar moves with constant velocity.

C If F is constant, the power of the resistor is approximately Fv.

D The current in the conducting bar will increase if B decreases.

33. Which one of the following has the largest energy content?

A 10^2 photons of wavelength 1 pm (γ-rays)

B 10^5 photons of wavelength 2 nm (X-rays)

C 10^6 photons of wavelength 5 μm (infra-red radiation)

D 10^8 photons of wavelength 600 nm (yellow light)

34. Of the following phenomena, which provides the best evidence that particles can have wave properties?

A The absorption of photons by electrons in an atom.

B The interference pattern produced by neutrons incident on a crystal.

C The production of x-rays by electrons striking a metal target.

D The scattering of photons by electrons at rest.

35. The speed of a moving electron is measured to be 1.95×10^6 m s^{-1}, to a precision of 0.50 %. What is the minimum uncertainty with which its position can be simultaneously measured?

A 5.9×10^{-9} m **B** 5.9×10^{-11} m

C 5.4×10^{-39} m **D** 5.4×10^{-41} m

36. Which of the following statements below on intrinsic semiconductors is true?

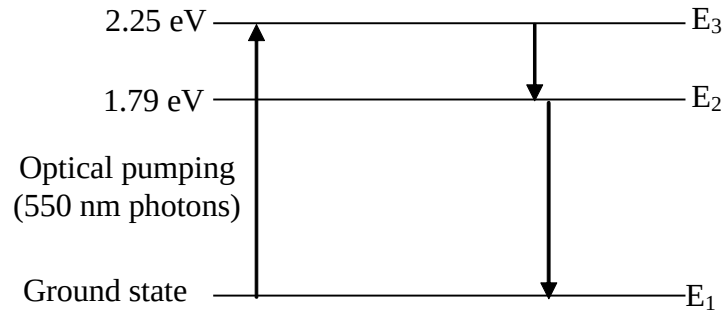
A The total current flow is due to the movement of the electron-hole pair.

B The valence band is completely filled and the conduction band is partially filled.

C There are more electrons in the conduction band than there are holes in the valence band.

D The valence band is completely filled and the conduction band is empty at room temperature.

37. In a ruby laser, light of wavelength 550 nm from a xenon flash lamp is used to excite the chromium (Cr) atoms in the ruby from ground state E_1 to state E_3. In subsequent de-excitations, laser light is emitted. Which of the following statements regarding this laser is **incorrect**?



A E_3 cannot be the metastable state because, if it is, then there will be no net production of light when equilibrium is reached, since stimulated absorption and stimulated emission will then occur at the same rate because the numbers of electrons in E_3 and E_1 will be the same at steady state.

B E_3 is the metastable state because, having a longer lifetime than a normal excited state, the metastable state allows the accumulation of excited electrons, resulting in population inversion and net light production.

C E_2 is the metastable state because it is not subject to stimulated emission caused by the 550 nm photons used in optical pumping, and so allows the accumulation of excited electrons to achieve population inversion.

D The transition from state E_2 to E_1 produces the laser light.

38. Which of the following statements concerning nuclear properties is true?

A The greater the binding energy of a nucleus, the more stable it is.

B If the total rest mass of the products of a reaction is greater than the total rest mass of the reactants, this reaction is impossible.

C The half-life of a radioactive substance can be changed by allowing the substance to react chemically to produce a new radioactive compound.

D When a stationary nucleus decays by emitting a γ-photon, the nucleus will move off in an opposite direction to the photon.

39. A radioactive nuclide **M** undergoes a series of decays to form **N**, which is an isotope of **M**. **M** most likely had undergone

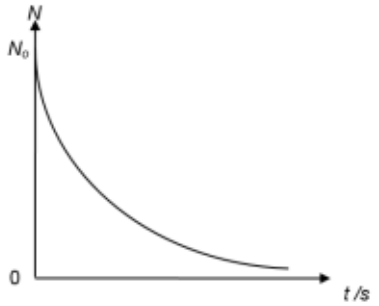
A 10 alpha and 5 beta decays

B 11 alpha and 11 beta decays

C 12 alpha and 4 beta decays

D 13 alpha and 26 beta decays

40. The figure (not to scale) below shows the variation with time t of the number of active nuclei N of a sample of radioactive nuclide. The initial number of nuclei is N_o. The half-life is $\ln(2^3)$ s.



Consider a tangent, **m,** to the curve drawn at the point N_o. **m** will cut the t-axis at

A $\frac{3}{\ln 2}$ s

B $\frac{3}{2\ln 2}$ s

C $\frac{3}{\sqrt{2}\ln 2}$ s

D $\frac{3\ln 2}{\ln 2}$ s

END of PAPER

NATIONAL JUNIOR COLLEGE

Preliminary Examinations
Higher 2

H

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

Paper 2 Structured Questions
Candidate answers on the Question Paper.

No Additional Materials are required.

9646/02
26 August 2016
1 hour 45 minutes

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	
2	
3	
4	
5	
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7	
8	
Total (72m)	

This document contains 17 printed pages, including this cover page.

Data

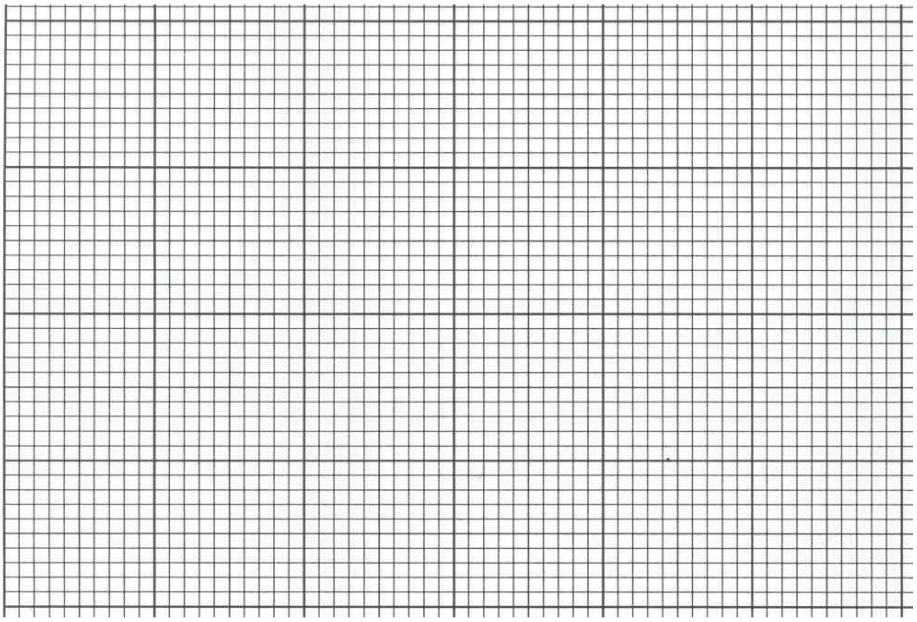
speed of light in free space,	$c = 3.00 \times 10^{8}\ ms^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1} = (1/(36\pi)) \times 10^{-9}\ F\ m^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ C$
the Planck 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,	$G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
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,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t \ \ and\ v = \pm\omega\sqrt{x_0^{\,2} - x^2}$
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,	$x = x_0 \sin \omega t$
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,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1(a) Two similar sports car A and B are used to do some road tests. They have different engines and thus provide different driving force. On a flat road, car A can accelerate uniformly from rest to 27.8 m s^{-1} in 3.5 s while car B can accelerate uniformly from rest to 27.8 m s^{-1} in 4.0 s.

(i) Using the figure below, draw the *velocity-time* graphs for the two cars, accelerating from rest together at the start line, for the first 4.0 s. Label **A** and **B** for the graph representing car A and car B respectively. [2]



(ii) Using the graphs draw in **(i)**, calculate the distance, d, between car A and B at t = 4.0 s.

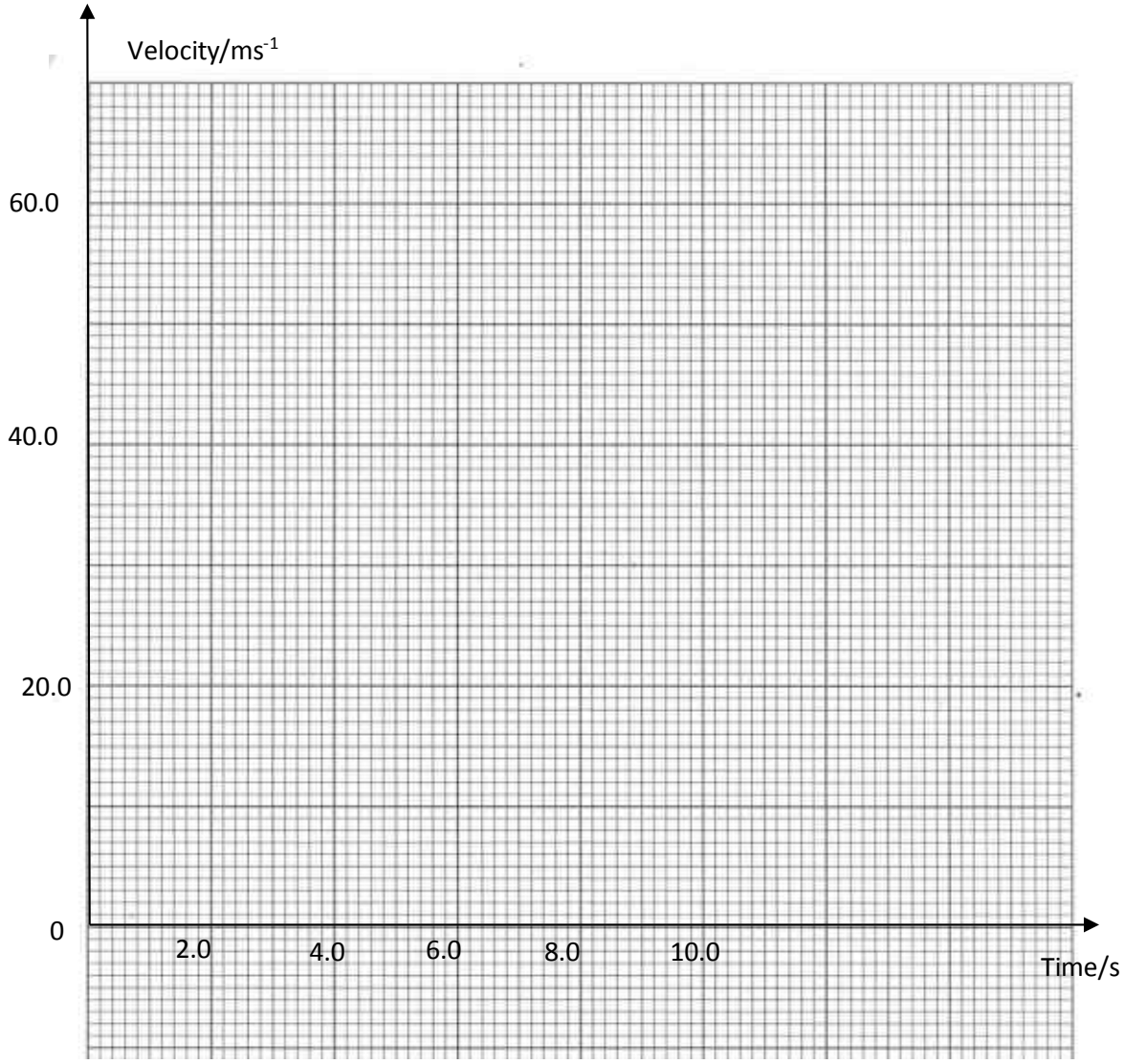
d =……m [2]

(b) (i) When both cars encounter a slope, driving force of car B remains the same while that of car A is reduced by 20%. Calculate the effective acceleration for each car A and B, denoted a_A and a_B respectively, when the cars move up a slope with an inclination of 30° with the horizontal.

a_A = ……..m s^{-2}

a_B = ……..m s^{-2} [2]

1(b) (ii) On a road test, car A enters a slope of 30° at 40 m s^{-1} while car B enters the slope at 37 m s^{-1} simultaneously at t = 0 s. Using the accelerations calculated in **1(b)(i)**, draw the *velocity-time* graphs in the axes provided below for car A and car B from t = 0 s to t = 10.0 s. [1]



(iii) Hence, explain qualitatively whether car B could overtake car A at t = 8.0 s.

……

……

……

……[2]

2 (a) **(i)** An object, immersed in a liquid in a tank, experienced an upthrust. Explain briefly the physical reason for this upthrust.

……

…… [1]

(ii) A thin plastic bag is found to have a mass m when empty and pressed flat. When the bag is filled with air, of volume V and density ρ, at atmospheric pressure and re-weighed, state and explain what would be the measured weight of the bag.

……

……

……

……[3]

(b) Consider a person bending as shown in Fig. 2.1. The force diagram for the spine of the person, with the back horizontal, can be shown in Fig. 2.2.



Fig. 2.1

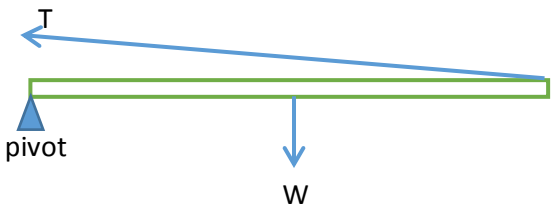


Fig. 2.2

The spine can be considered as a rod pivoted at its base. The various muscles of the back are equivalent to a single muscle producing a force T as shown. W is the force that the upper part of the body exerts on the spine.

(i) State and explain qualitatively the value of T, relative to W, at equilibrium.

……

……

……[2]

(ii) On Fig. 2.2 , draw a force, F, at the pivot which is necessary for equilibrium. Hence, state and explain qualitatively the value of F, relative to W.

……

…… [2]

3 (a) Explain:

(i) what is meant by a plane-polarised wave;

……

…… [1]

(ii) why sound waves cannot be polarised.

……

…… [1]

(b) Figs. 3.1 and 3.2 show an experiment in which a student observes two parallel beams of light through a Polaroid filter. In Fig. 3.1, the beam consists of unpolarised light of intensity I_o. In Fig. 3.2, the beam is plane-polarised with intensity I_1.

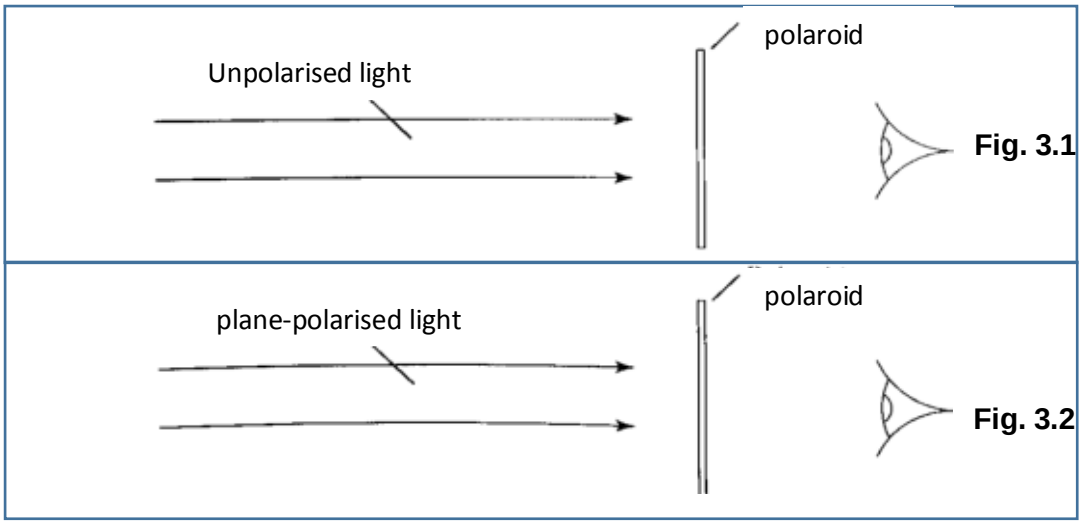
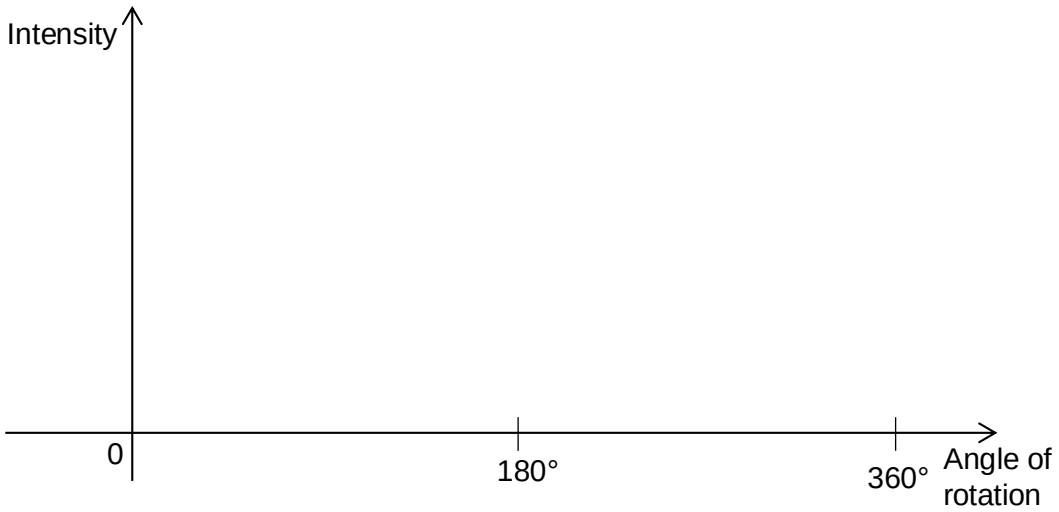


Fig. 3.1

Fig. 3.2



On the axes above, sketch two graphs, labelled **(1)** and **(2),** corresponding to Fig. 3.1 and Fig. 3.2 respectively, to show how you might expect the intensity of the light reaching the student to vary as the polaroid in each case is turned 360° in its own plane. [2]

(c) Light from a low pressure sodium lamp consists mostly of two wavelengths, 589.99 nm and 589.59 nm. This light is allowed to fall normally on a diffraction grating with 500 lines per millimetre. Describe quantitatively the pattern which would be observed.

[2]

4 (a) Fig. 4.1 shows how the electric potential, *V,* varies with $\frac{1}{r}$, where *r* is the distance from a point charge *Q*.

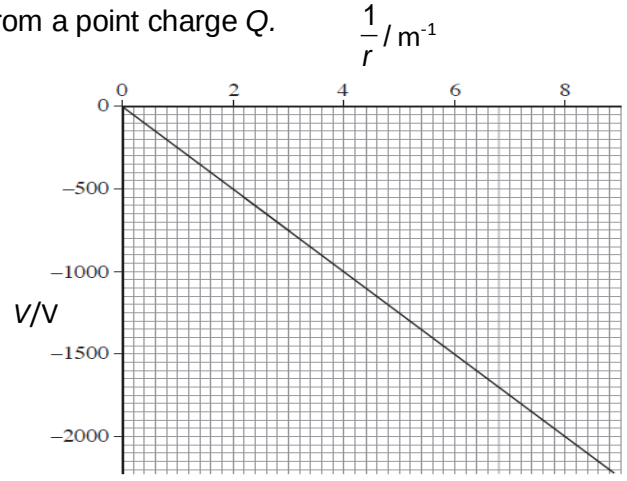


Fig. 4.1

State what can be deduced from the graph about how *V* depends on *r* and explain why all the values of *V* on the graph are negative.

……

……

……[2]

(b) Two positively charged metal spheres A and B are situated in a vacuum, as shown in Fig. 4.2.

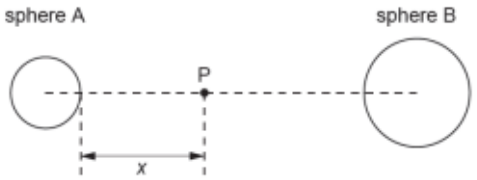


Fig. 4.2

A point P lies on the joining the centres of the two spheres and is a distance *x* from the surface of sphere A.

The variation with *x* of the electric potential *V* due to the two charged spheres is shown in Fig. 4.3.

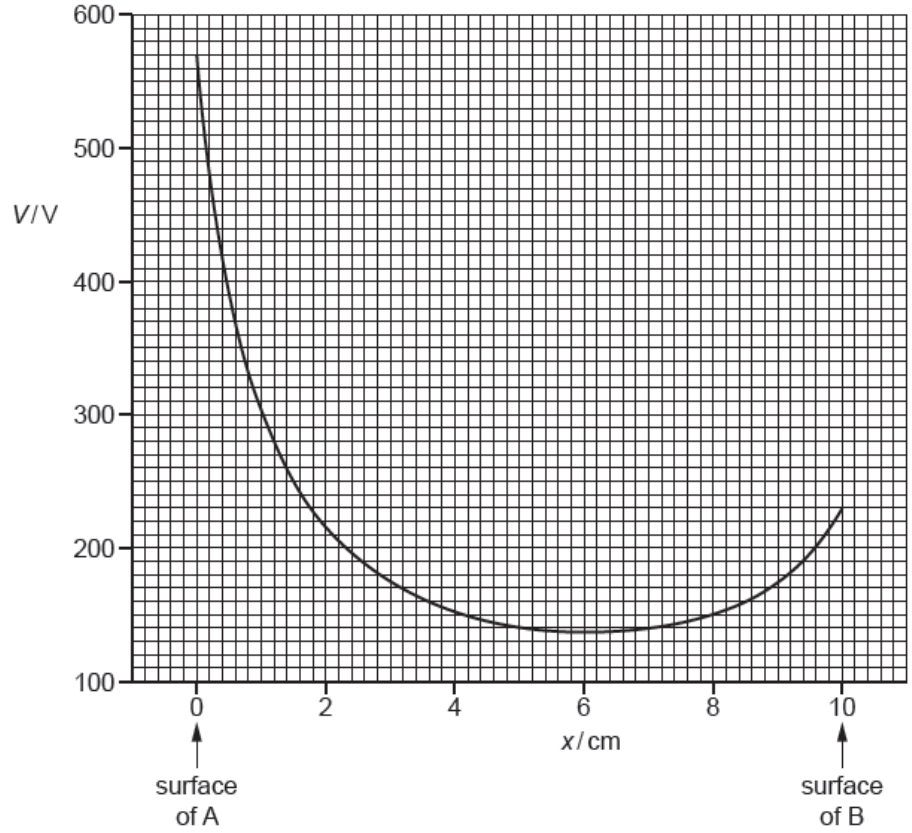


Fig. 4.3

(i) State how the magnitude of the electric field strength at any point may be determined from the graph of Fig. 4.3.

……

…… [1]

(ii) Without any calculations, describe the force acting on a positively charged particle placed at point P for values of x from x = 0 to x = 10 cm.

……

……

……

……[3]

(c) The positively charged particle in **(b)(ii)** has charge q and mass m given by the expression

$$\frac{q}{m} = 4.8x10^{7}\ \text{Ckg}^{-1}$$

Initially, the particle is at rest on the surface of sphere A where $x = 0$. It then moves freely along the line joining the centres of the sphere until it reaches the surface of sphere B.

Calculate the speed, v, of the particle as it reaches the surface of sphere B. Explain your working.

v = ...ms^{-1} [2]

5 (a) Fig. 5.1 illustrates a fixed rectangular coil whose lower horizontal side, XY, lies between the poles of a magnet placed on the platform of a top-pan balance.

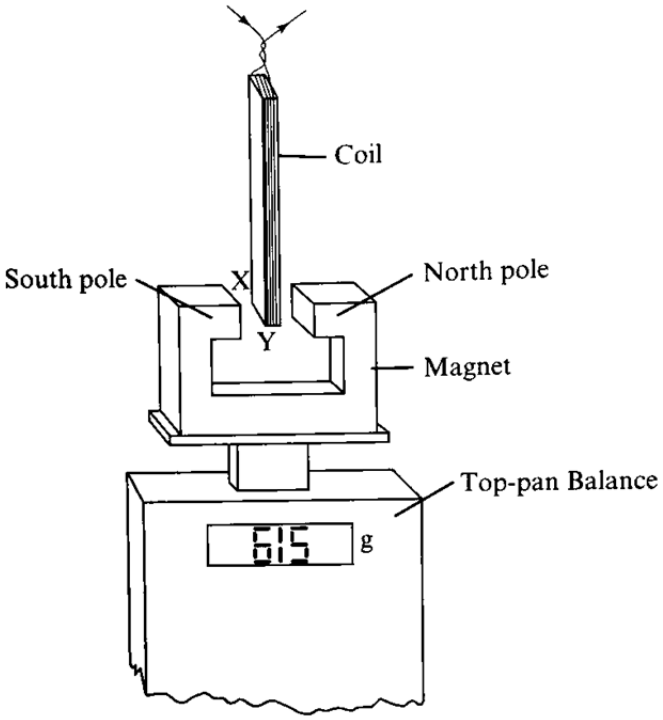


Fig. 5.1

With no current in the coil, the balance records the mass of the magnet. State and explain how the reading of the balance changes when the current is switched on. You may assume a direct current flows from X to Y.

……..

……..

……[2]

(b) In a moving-coil loudspeaker, a circular coil of wire, the speech coil, is free to move in the circular gap between the cylindrical core (South pole) and the surrounding ring (North pole) of a magnet, as shown in Fig. 5.2. The speech coil is attached to the speaker cone.

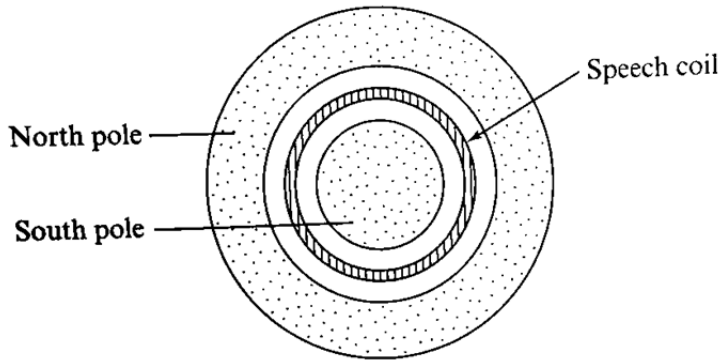


Fig. 5.2

(i) The speech coil, with a mean radius of 25 mm, consists of 120 turns of wire. The flux density of the radial field in which the coil lies is 0.45 T. Calculate the electromagnetic force, F, on the coil when a current of 15 mA passes through it.

F =……N [2]

(ii) Explain how audio-frequency vibrations of the speaker cone are brought about.

……

……

……[2]

6 (a) Fig. 6.1 shows the variation of intensity I with wavelength λ of a typical X-ray spectrum.

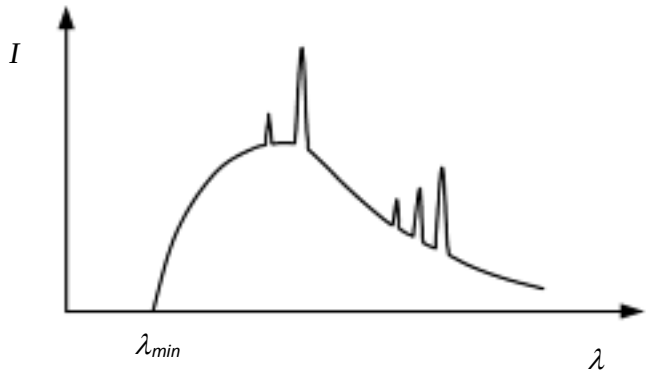


Fig. 6.1

By reference to the principles of production of X-rays in an X-ray tube, explain the origins of any two main features of the spectrum using quantum theory.

……

……

……

……

……

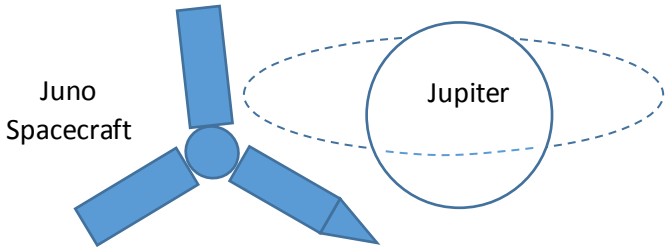
……[3]

(b) Suppose the ionisation energy of an atom is 4.10 eV. In the spectrum of this same atom, we observe emission lines with wavelengths 310 nm, 400 nm, 1378 nm.

Use this information to construct the energy-level diagram with the fewest levels. Assume the higher levels are closer together.

[4]

7 It was reported on 6 July 2016 in the news that NASA's Juno spacecraft reached the desired orbit around Jupiter. The mission was to find out more about Jupiter.



Jupiter has many moons. Fig.7.1 shows the period and orbital distance of some of the moons found around Jupiter.

Moon	Period, T/Days	Orbital Distance, r/10^8 m
Metis	0.295	1.28
Unknown	0.38	1.85
Thebe	0.67	2.22
Io	1.77	4.22
Europa	3.55	6.71
Ganymede	7.16	10.7
Callisto	16.7	18.8

Fig.7.1

(a) The variation with orbital distance r of the period T is given by the expression

$$T = kr^{m/n}$$

(i) Theory suggest that m/n = 1.5. Use Fig.7.1 to show that the data supports this suggestion. [2]

(ii) A graph of some of the data showing the variation of lg (T/days) with lg (r/m) is shown in Fig.7.2**.**

On Fig 7.2,

1. Plot the point corresponding to r = 4.22 x 10^8 m,
2. Draw the line of best fit for all the points. [2]

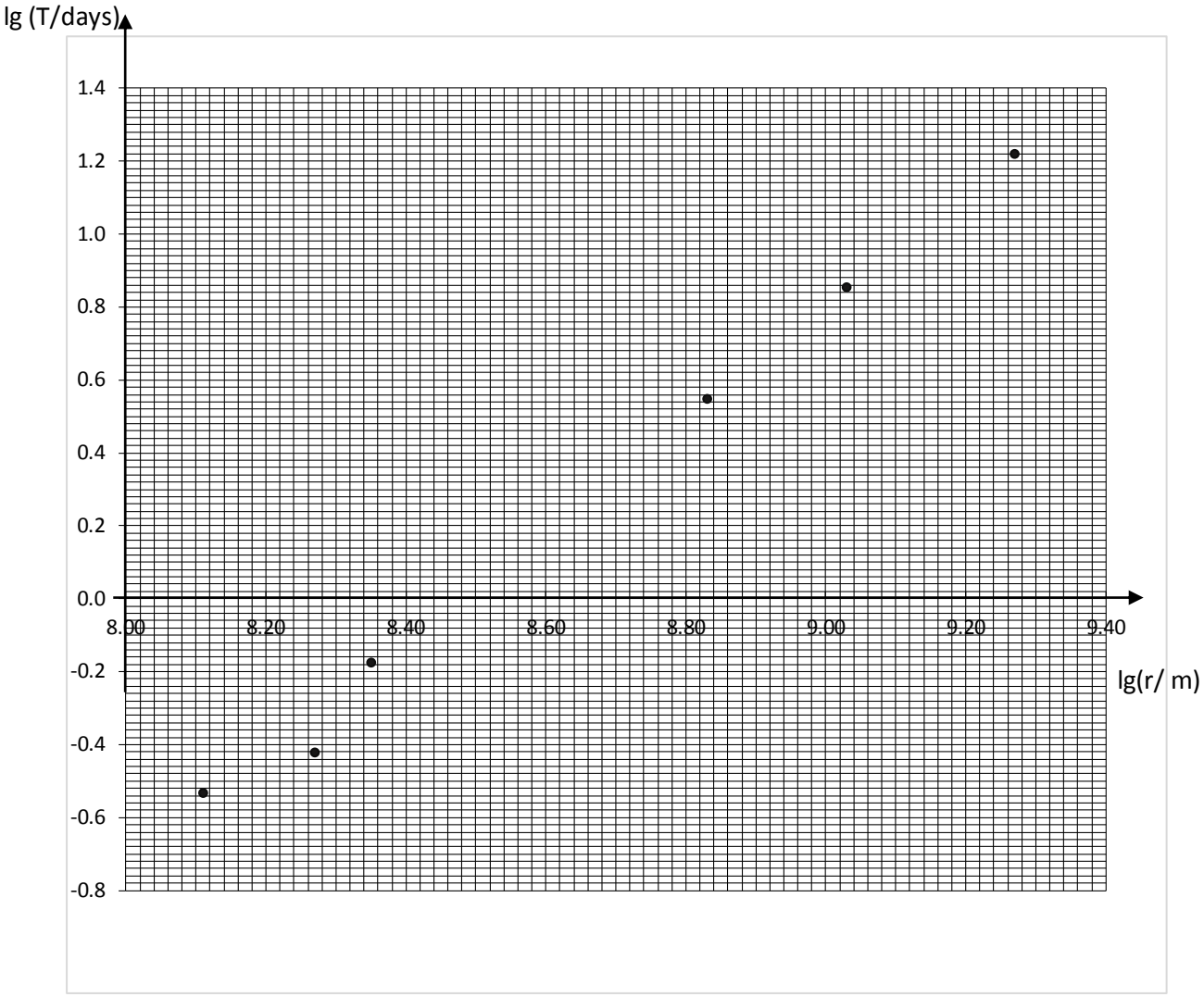


Fig. 7.2

(iii) Determine the gradient of the line you have drawn on Fig.7.2.

Gradient = …… [2]

(iv) Explain why the graph of Fig.7.2 supports the expression given in **7(a).**

……

……[2]

(v) State values of the integer m and n.

m =…….. and
n=…….. [1]

(vi) Given k = $\sqrt{\frac{4\pi^2}{GM}}$ where M is the mass of Jupiter, determine the mass of Jupiter.

M = ……kg [2]

(b)(i) **1.** The intensity of sunlight from the Sun reaching Earth is about 1400 W m^{-2}. Jupiter is 5.2 times the distance from the Earth to the Sun. Show that the intensity of the Sunlight reaching Jupiter is about 50 W m^{-2}. [1]

2. It was reported that the Juno's Solar array of 60 m^2 can produce about 500 W of power. Calculate the efficiency of the Solar array on Juno's spacecraft.

Efficiency =…….%[2]

(ii) Juno Spacecraft passed through Jupiter's north pole where it encountered radiation of high speed electrons. Its crucial system was shielded by a titanium vault. Suggest a reason for the need to shield the Juno's spacecraft system from the high speed electrons.

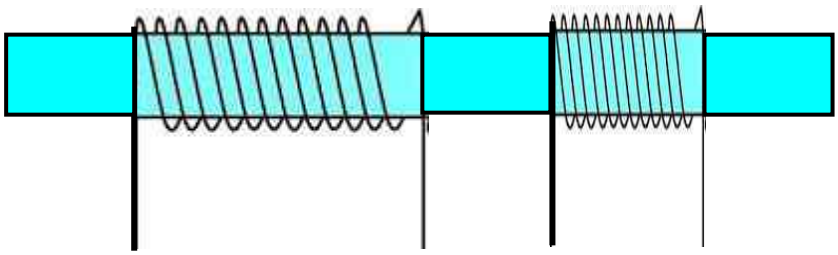
……..

……

……

……[2]

8 A simple transformer can be made by winding coils of copper wire around a solid hard iron core.



It is suggested that the efficiency of such a transformer can be affected by the power supplied to it.

Design an experiment using a simple transformer to find out how the efficiency of the transformer varies with the frequency of the power supply. You should draw a labelled diagram to show the arrangement of your apparatus. In your account, you should pay particular attention to

(i) the identification and control of variables,
(ii) the procedure to be followed
(iii) how the efficiency is calculated
(iv) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram:

……

……

……

NATIONAL JUNIOR COLLEGE
PRELIMINARY EXAMINATIONS
Senior Higher 2

H

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS (Section A)

Paper 3 Longer Structured Questions

9646/03
31 Aug 2016
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 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.

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	
2	
3	
4	
5	
Total (40m)	

This document consists of 11 printed pages, including this cover page.

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	$p = \rho g h$
gravitational potential,	$\phi = -\frac{GM}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos\omega t \text{ and } v = \pm\omega\sqrt{(x_0^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + \ldots$
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,	$x = x_0 \sin \omega t$
transmission coefficient	$T \propto \exp(-2kd) \text{ where } k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 (a) (i) By reference to equations of motion, derive an expression for the kinetic energy, E_k, of an object of mass m moving at speed v.

[2]

(ii) It is often stated that many forms of transport transforms chemical energy into kinetic energy. Explain briefly why a cyclist travelling at constant speed is not making such transformation.

……

……

……

……[2]

(b) A car, of mass 720 kg, travelling along a horizontal road with a constant speed of 31 ms^{-1} would require a power of 36.6 kW.

(i) Determine the work done in overcoming the external forces opposing the motion of the car during a time of 5.0 minutes.

workdone = …….. J [2]

(ii) Hence, with reference to **(b)(i)**, suggest, with a reason, whether it would be worthwhile to develop a system whereby when the car slows down, its kinetic energy would be stored for re-use when the car speeds up again.

……

……

……

……[2]

2 (a) Show how the conservation of linear momentum can be derived using Newton's laws.

[3]

(b) When two strong magnets are held stationary with the north pole of one pushed against the north pole of the other. On letting go, the magnets spring apart. It is apparent that the kinetic energy of the magnets has increased.

(i) Explain how the law of conservation of momentum applies in this case.

……

……

……[1]

(ii) Suggest why the kinetic energy of the magnets increased.

……

……

……[1]

2 (c) A small block of mass $2m$ initially rests on a track at the bottom of the circular, vertical loop as shown in Fig. 2.1, which has a radius r. A bullet of mass m strikes the block horizontally with initial speed v_0 and remains embedded in the block as the block and bullet circle the loop.

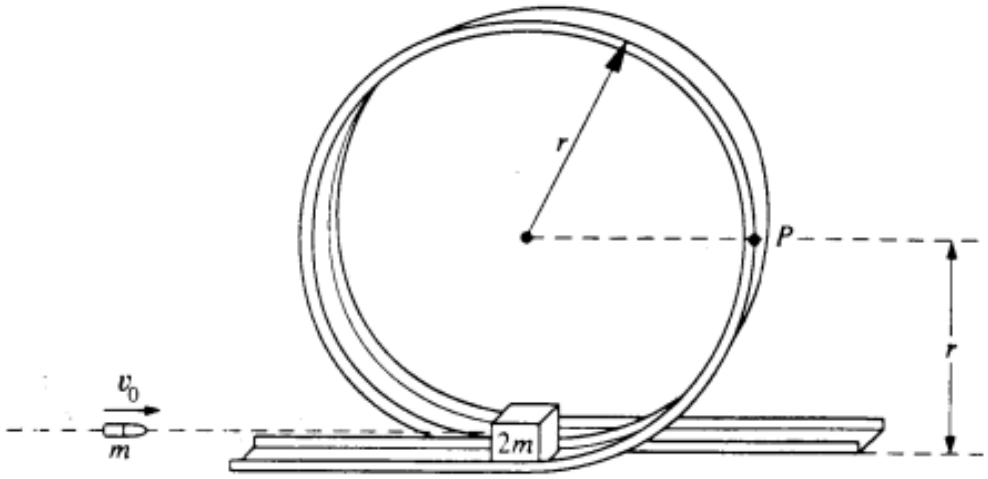


Fig. 2.1

Determine the minimum v_0 in terms of r and g, clearly stating any assumption(s) made, to ensure the block and bullet remain in contact with the track at all times.

v_0 = ... [3]

3 (a) The Fig. 3.1 below shows a simple potentiometer circuit. AB is a uniform resistance wire.

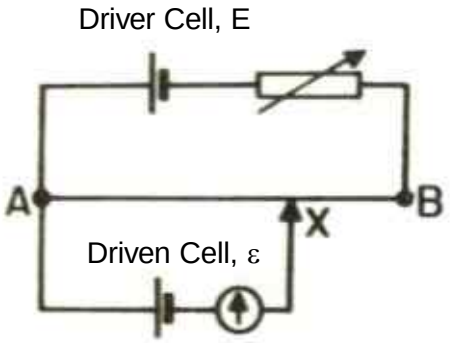


Fig. 3.1

(i) Explain why a point X may be found on the wire which gives zero galvanometer deflection.

……

……

……

…….. ……[2]

(ii) When the circuit was first setup it was impossible to find a balance point X in reality. State and explain one possible cause of this.

……

……

……[1]

(iii) When the circuit is properly setup, explain why is this circuit not suitable for the comparison of an e.m.f of a few millivolts with an e.m.f of about a volt.

……

……

……

…….. ……[2]

3 (b) The circuit in the Fig. 3.2 may be used to measure the e.m.f of a thermocouple. Both galvanometer show no deflection.

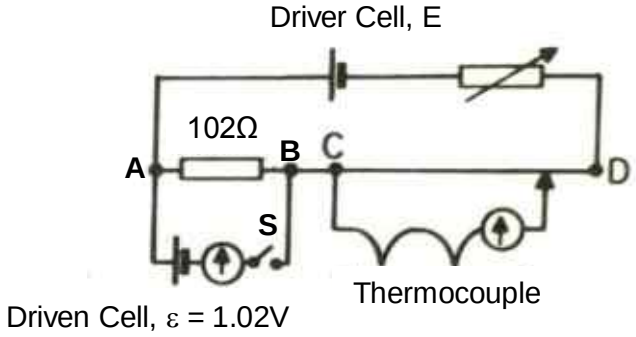


Fig. 3.2

(i) State the potential difference across the AB when the switch S is closed.

potential difference = …….…….. V [1]

(ii) Referring to the circuit in Fig. 3.2 with switch S closed, if the resistance of uniform wire CD were 2.00 Ω, its length were 1.000 m and the balance length were 79.0 cm, what would be the e.m.f of the thermocouple?

e.m.f = ……. V [3]

4 (a) An experiment is performed to investigate the magnetic field strength inside a 100 mm long solenoid of 500 turns. A small single loop of wire attached to a voltage sensor is lowered coaxially inside the solenoid, as shown in the Fig. 4.1, until it is at the centre of the solenoid.

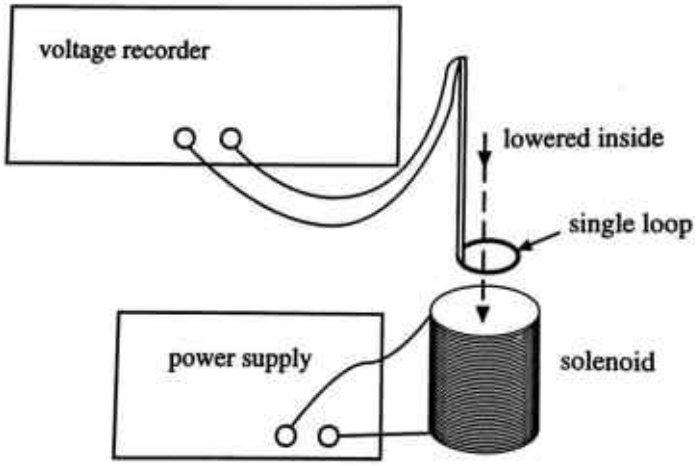


Fig. 4.1

The solenoid is supplied with a steady current of 0.50 A.
The magnetic flux density, *B* at a point on the axis well inside a long solenoid is given by

$$B = \frac{\mu_o NI}{l}$$

where *N* is the number of turns on the solenoid, l is the length of solenoid, μ_0 is permeability of free space and I is the current flowing in the solenoid.

The single loop of wire is positioned at the centre of the solenoid so that it is at right angles to the magnetic field. If the loop has an area of 160 mm^2, calculate the magnetic flux through the loop.

magnetic flux = ... Wb [1]

4 (b) The current through the solenoid is decreased to a lower value at a steady rate and the graph as shown in Fig. 4.2 is obtained using data from the voltage sensor.

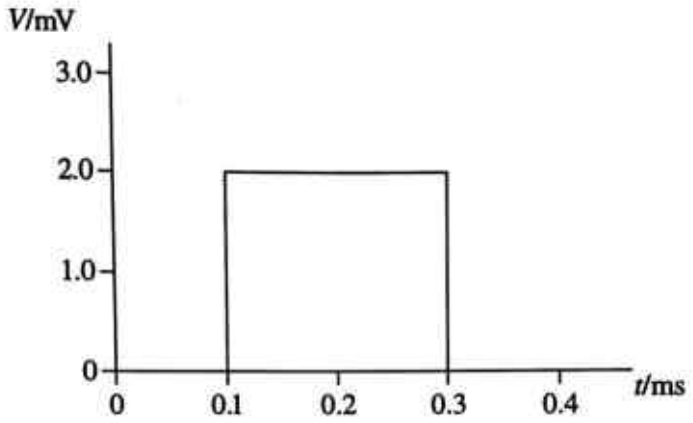


Fig. 4.2

(i) Calculate the change of flux through the loop.

change in magnetic flux = ... Wb [1]

(ii) Determine the new value of the current flowing in the solenoid.

current = ... A [1]

4 (c) Fig. 4.3 shows a coil of copper wire made up of two semicircles joined by two straight sections of wire. The total resistance of the coil is 0.025 Ω. The coil is lying flat on a horizontal surface. Starting from the orientation in Fig. 4.3, the smaller semicircle of radius 0.20 m rotates at an angular frequency 1.5 $rads^{-1}$ about the dashed line. The angle θ is the angle of rotation measured from the horizontal position as shown in Fig. 4.4. A uniform magnetic field of magnitude 0.35 T is directed upwards, perpendicular to the horizontal surface.

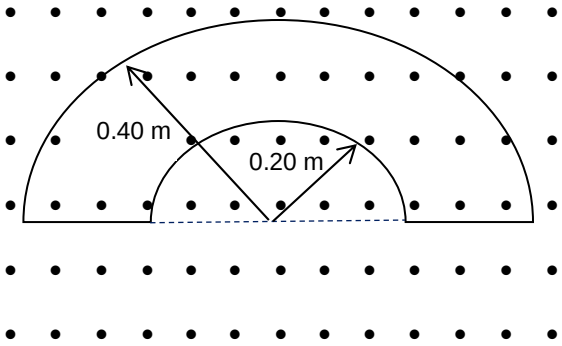


Fig. 4.3: Top View

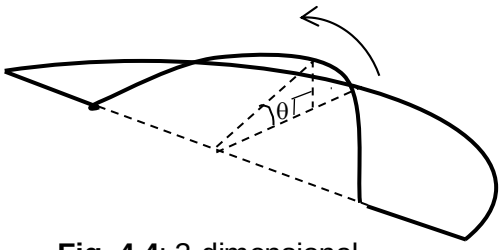


Fig. 4.4: 3-dimensional

(i) On the axes below, sketch the variation of the magnetic flux, Φ through the coil with θ, for one full cycle. Indicate all the important values. [2]



(ii) Hence, sketch on the axes below, the variation of the induced emf, E in the coil with time, t for one complete cycle. [2]



5 (a) Describe the origin of the depletion region at the pn junction.

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……[4]

(b) A pn junction is placed in the circuit as shown in Fig. 5.1.

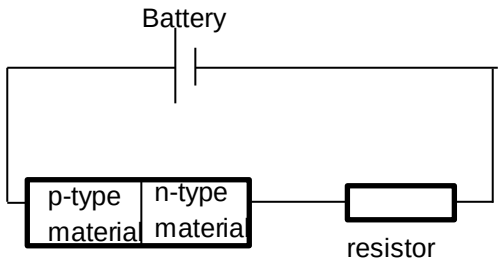

Fig. 5.1

(i) Referring to the circuit in Fig. 5.1, identify if the pn junction is forward bias or reversed bias.

…… bias [1]

(ii) Describe the origin of the bias connection that you have identified in **(b)(i).**

……

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……

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……

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……[3]

END OF Section A

NATIONAL JUNIOR COLLEGE
PRELIMINARY EXAMINATIONS
Senior Higher 2

H

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS (Section B)

Paper 3 Longer Structured Questions

9646/03
31 Aug 2016
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 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.

For Examiner's Use	
6	
7	
8	
Total (40m)	

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.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ ms^{-1}
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acceleration of free fall,	$g = 9.81$ ms^{-2}

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hydrostatic pressure	$p = \rho g h$
gravitational potential,	$\phi = -\frac{GM}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos\omega t \text{ and } v = \pm\omega\sqrt{(x_0{}^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + \ldots$
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,	$x = x_0 \sin \omega t$
transmission coefficient	$T \propto \exp(-2kd) \text{ where } k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section B

Answer **two** questions from this Section in the spaces provided.

6 (a) Distinguish between *frequency* and *angular frequency* for a body undergoing simple harmonic motion.

……

……

……[1]

(b) A rod is mounted on a rotating turntable, rotating anticlockwise with a constant angular velocity. The setup is illuminated from the left by a light source. The rod forms a shadow X on the screen at the right hand side, as shown in Fig. 6.1. Explain clearly, with suitable workings, why the motion of the shadow is simple harmonic.

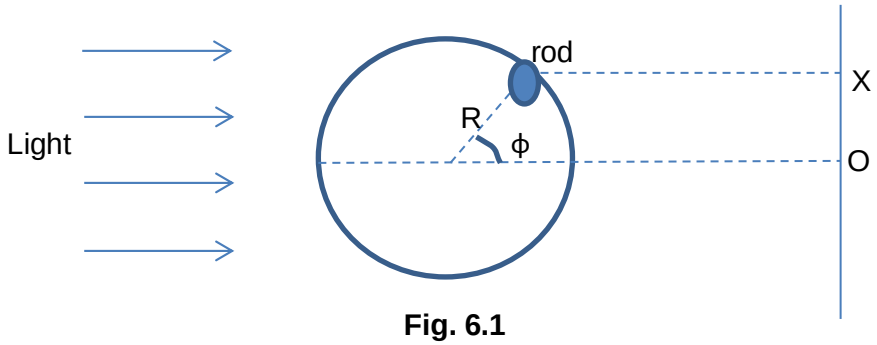

Fig. 6.1

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……

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……

……[3]

6 (c) Fig. 6.2 shows a simple pendulum consisting of a steel sphere suspended by a light string from a rigid support. The sphere is displaced 50 mm from its vertical equilibrium positon and released at $t = 0$.

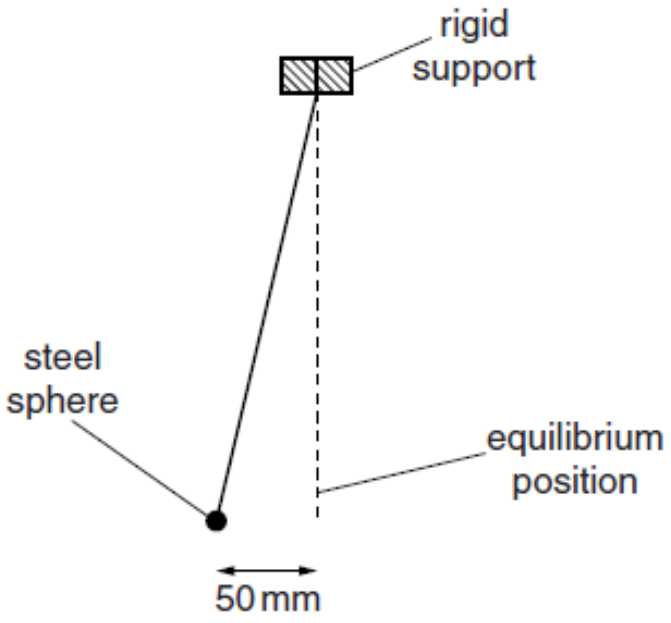


Fig. 6.2

not to scale

Fig. 6.3 shows the graph of displacement x of the sphere against t.

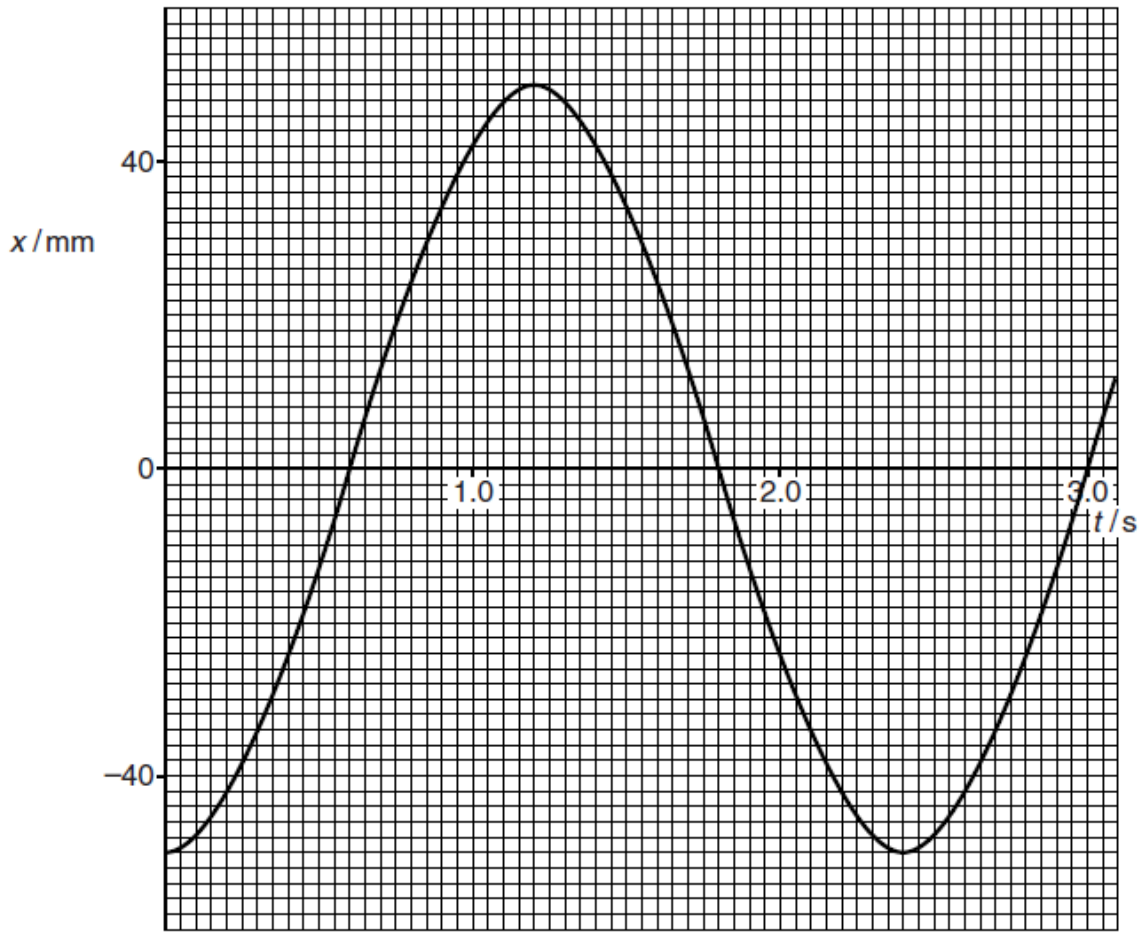


Fig. 6.3

6 (c) The sphere is now released from rest with a displacement x= 25 mm.

(i) State with a reason, the change if any in the maximum kinetic energy of the sphere.

……

……

……

……[2]

(ii) Sketch the kinetic energy of sphere vs time for $0 < t < 5.0$ s on Fig. 6.4. [1]

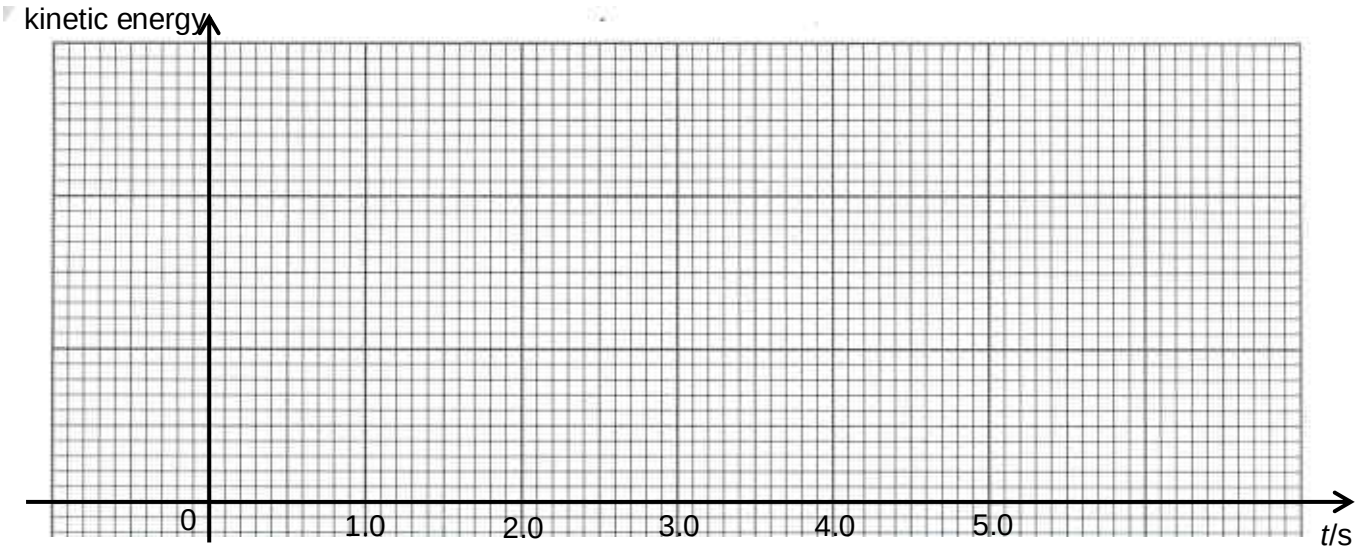


Fig. 6.4

(d) When violet light falls on a sheet of barium metal held by an insulating stand for a very long time, the barium acquires a charge. Explain clearly which sign of charge would be acquired.

……

……

……

……[2]

(e) Use the theory of the particulate nature of electromagnetic radiation to explain why there is no time delay in emission of photoelectrons for the photoelectric effect.

……

……

……

……[2]

6 (f) Fig. 6.5 is a graph showing the maximum kinetic energy energies of electrons emitted from a metal surface by light of different frequencies from a hydrogen light source.

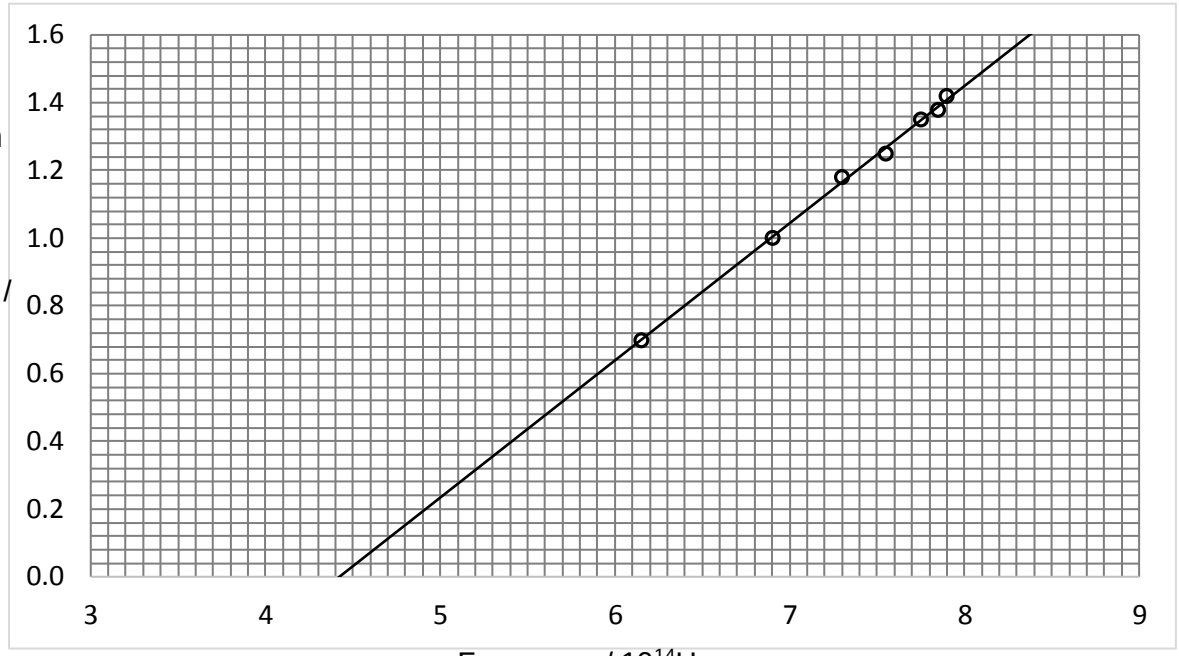


Fig. 6.5

The frequencies of light from the lamp, shown by the small circles on the Fig. 6.5 are the only frequencies obtained in this range. State and explain what can be deduced from the energy levels in hydrogen atoms.

……

……

……

……

……

……[3]

6 (g) Electrons are emitted from a metal surface when light of a particular wavelength is incident on the surface. Explain why the emitted electrons have a range of values of kinetic energy below the maximum kinetic energy of photoelectrons.

……

……

……

……[2]

(h) From experimental observation, electrons of suitable energies are strongly scattered in certain directions by crystalline solid.

(i) Explain why a crystalline solid is required for this experiment.

……

……[1]

(ii) Deduce the nature of the behaviour of electrons from the above experimental observations. Explain clearly why electrons with certain energies could exhibit such behaviour.

……

……

……

……[3]

7 **(a)** The equation of state of an ideal gas is $PV = nRT$. Data about gases are often given in terms of density ρ rather than volume V. Show that the equation of state for a gas can be written as $P = \rho RT/M_R$ where M_R is the mass of one mole of gas.

[2]

(b) One simple model of the atmosphere assumes that air behaves as an ideal gas at a constant temperature. Using this model the pressure P of the atmosphere at a temperature of 20 °C varies with height h above the Earth's sea level as shown in Fig. 7.1.

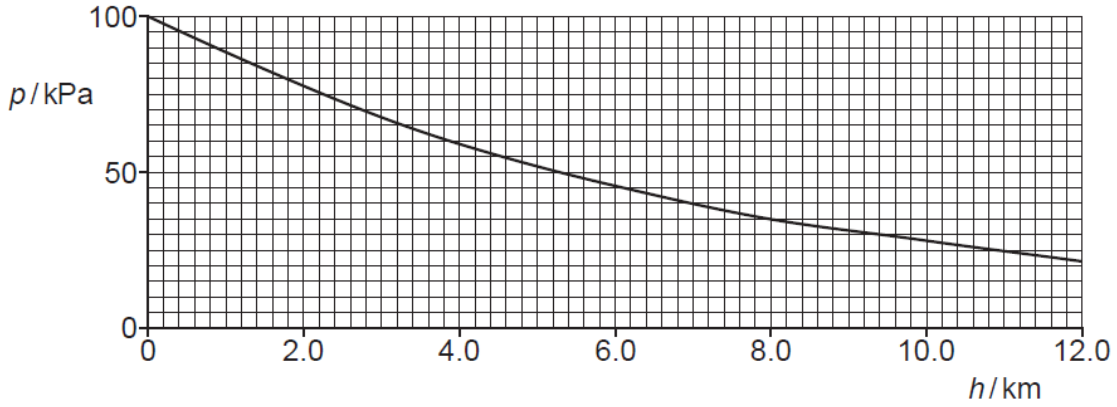


Fig. 7.1

(i) The ideal gas equation in **(a)** shows that, at constant temperature, pressure P is proportional to density ρ. Use data from Fig. 7.1 to find the density of the atmosphere at a height of 8.0 km.
Density ρ of air at sea level is 1.3 kg m^{-3}.

ρ = ... kg m^{-3} [3]

7 (b) (ii) In the real atmosphere the density, pressure and temperature all decrease with height. At the summit of Mt. Everest, 8.0 km above sea level, the pressure is only 0.30 of that at sea level.
Take the temperature at the summit to be –23 °C and at sea level to be 20 °C.
Calculate, using the ideal gas equation, the density of the air at the summit.

density = …….. kg m^{-3} [3]

(iii) Using the kinetic theory, explain any changes to specific latent heat of vaporisation of water at the summit of Mt Everest as compare to at the sea level.

……

……

……

……[2]

7 (c) 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. 7.2 and Fig. 7.3.

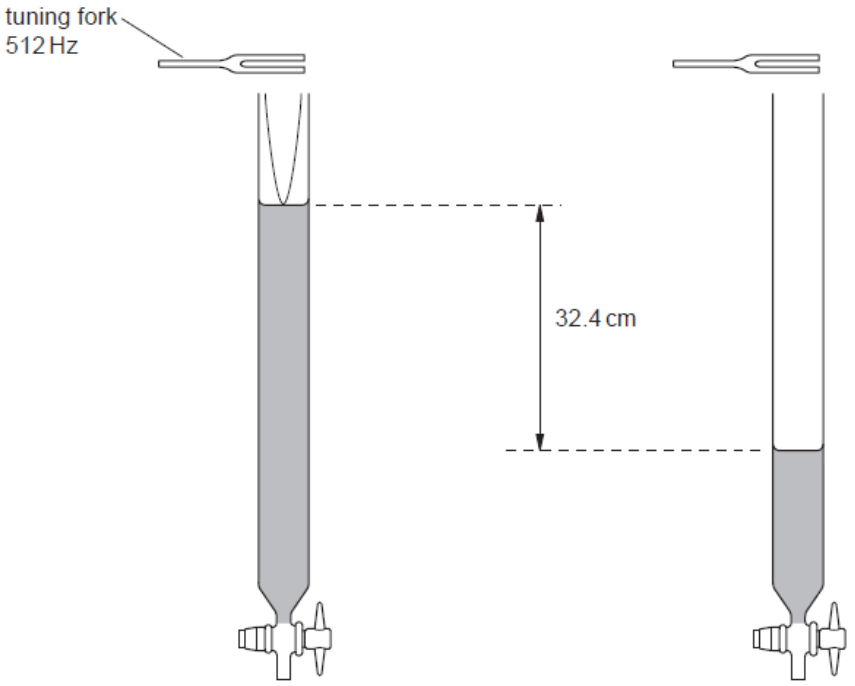


Fig. 7.2 **Fig. 7.3**

A loud sound is first heard when the water level is as shown in Fig. 7.2, and then again when the water level is as shown in Fig. 7.3. Fig. 7.2 illustrates a stationary wave produced in the tube.

(i) Explain the formation of a stationary wave in the tube.

……

……

……

……[2]

(ii) Explain, by reference to resonance, why the loudness of the sound changes as the water level changes.

……

……

……

……

……

……[3]

7 (c) (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} [3]

(iv) The length of the column of air in the tube in Fig. 7.2 is 15.7 cm. Suggest and explain where the antinode of the stationary wave produced in the tube in Fig. 7.2 is likely to be found.

……

……

……

……[2]

8 (a) Classic experiments on alpha-particle scattering were performed by Rutherford.

State the experimental observation obtained from such experiments which suggested that

(i) the nucleus is small

……

……..[1]

(ii) the nucleus is massive and charged.

……

……..[1]

(b) **(i)** Define Nuclear Fusion.

……

……..[1]

(ii) By definition, the mass of the $^{12}_{6}C$ atom is 12u exactly. Explain why the sum of the masses of the constituents of the $^{12}_{6}C$ atom is not 12 *u* exactly. The masses of the electron, proton and neutron are 0.00055 *u*, 1.00728 *u* and 1.00867 *u* respectively.

……

……

……

……..[2]

8 **(b)** **(iii)** Uranium nuclei when bombarded by neutrons may undergo nuclear

reactions. One such reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$$

1. Determine the energy change in this reaction. The binding energy per nucleon of $^{235}_{92}U$, $^{144}_{56}Ba$ and $^{90}_{36}Kr$ are 7.5 MeV, 8.5 MeV and 8.5 MeV respectively.

energy change = …… J [1]

2. Suggest two forms of energy into which the energy calculated above is transformed during a reaction of this type.

……

……

……..[2]

8 (c) An experiment is carried out in which the count rate is measured at a fixed distance from a sample of a certain radioactive material. The decay process is random and spontaneous. Fig. 8.1 shows the variation of count rate with time t that was obtained.

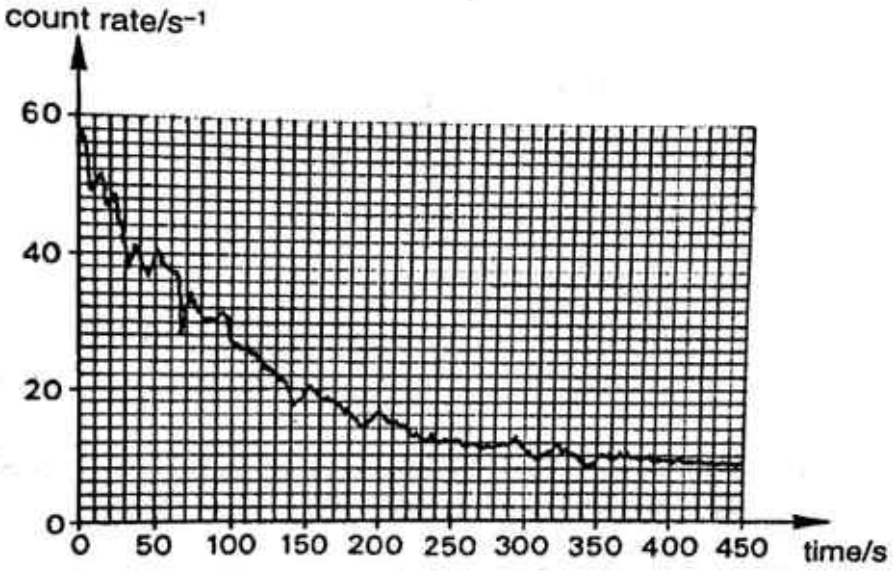


Fig. 8.1

(i) Define the terms *random* and *spontaneous*.

……

……

……

……[2]

(ii) Explain why the random nature of radioactive decay makes it difficult to measure the value of half-life to a high degree of accuracy.

……

……

……

……[2]

8 (c) (iii) Use Fig. 8.1 to estimate the half-life of the material.

half-life = …….. s [2]

(iv) The material which may emit γ-rays is to be transported in a sealed wooden box, which is a lead container surrounded by expanded-polystyrene as shown in Fig. 8.2.

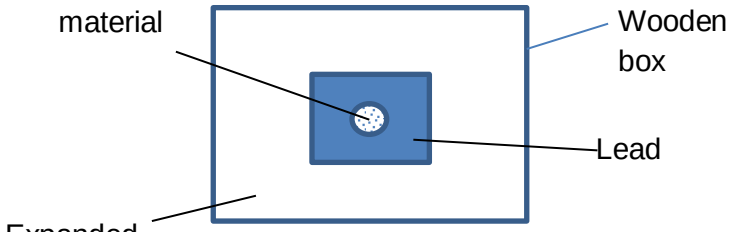


Fig. 8.2

Suggest why, on health grounds, the source is placed in a lead container surrounded by expanded polystyrene.

……

……

……

……[2]

8 (d) Radioactive iron has a half-life of 46 days. It is used medically in the diagnosis of blood disorders. Measurements are complicated by the fact that iron is excreted, i.e. removed, from the body at a rate such that 69 days after administering a dose, half of the atoms in the dose have been excreted.

If the count rate from a blood sample is 960 counts per minute, calculate the count rate from a similar blood sample taken 138 days later.

count rate = …….. min^{-1} [4]

END OF PAPER

2016 NJC H2 Physics Prelim Suggested Solutions

Paper 1

1	C	11	D	21	C	31	D
2	D	12	B	22	A	32	C
3	B	13	C	23	A	33	D
4	C	14	D	24	B	34	B
5	D	15	B	25	B	35	A
6	D	16	C	26	B	36	A
7	C	17	D	27	B	37	B
8	A	18	B	28	D	38	D
9	A	19	A	29	C	39	D
10	A	20	A	30	D	40	D

Paper 2

1 (a)(i)

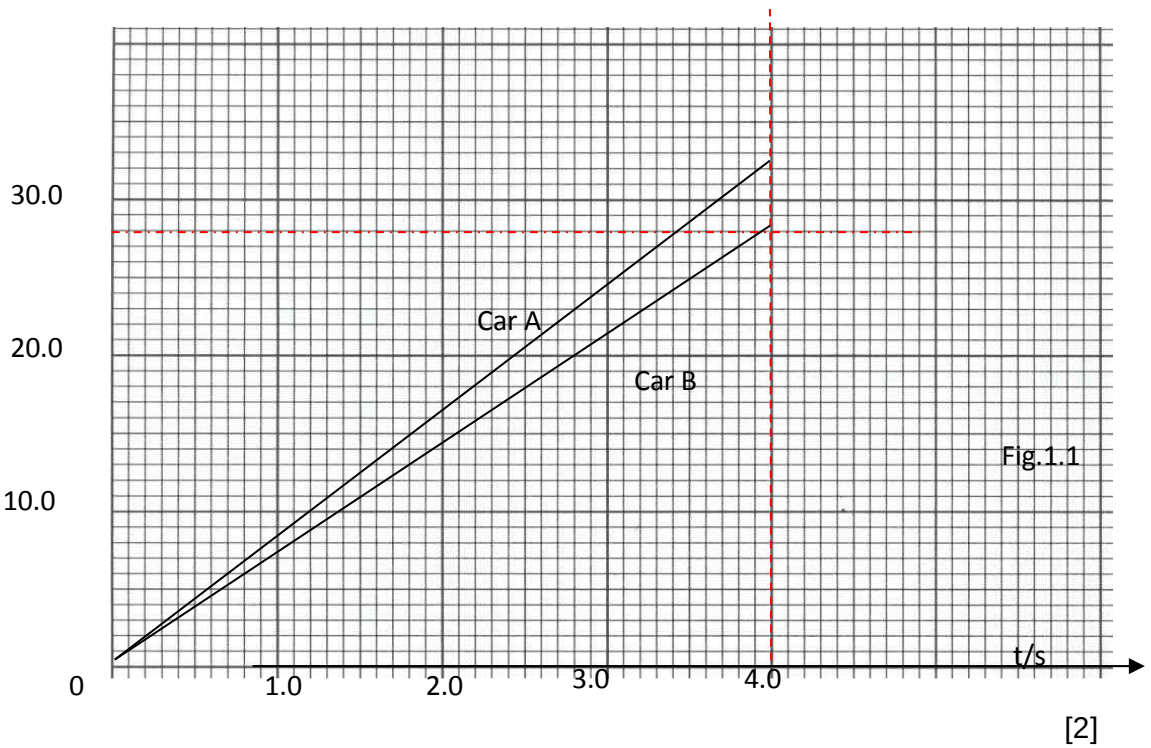


Fig.1.1

[2]

1 (a)(ii) Distance travelled by car A = ½ x 4.0 x 32.0 = 64.0 m

Distance travelled by car B = ½ x 4.0 X 27.8 = 55.6 m

Distance between the cars = 64.0 - 55.6 = **8.4 m**

1 (b)(i) Acceleration of car A, $a_A = 27.8/3.5 = 7.94\ ms^{-2}$

Acceleration of car B, $a_B = 27.8/4.0 = 6.95\ ms^{-2}$

Effective acceleration of car A = $a'_A = (a_A \times 0.8) - g\sin 30^o$

$= 7.94 \times 0.8 - 9.81\ (0.5)$

$= 1.447 =$ **$1.45\ m\ s^{-2}$**

Effective acceleration of car B = $a'_B = a_B - g\sin 30^o$

$= 6.95 - 9.81\ (0.5) = 2.045 =$ **$2.05\ m\ s^{-2}$**

1 (b)(ii)

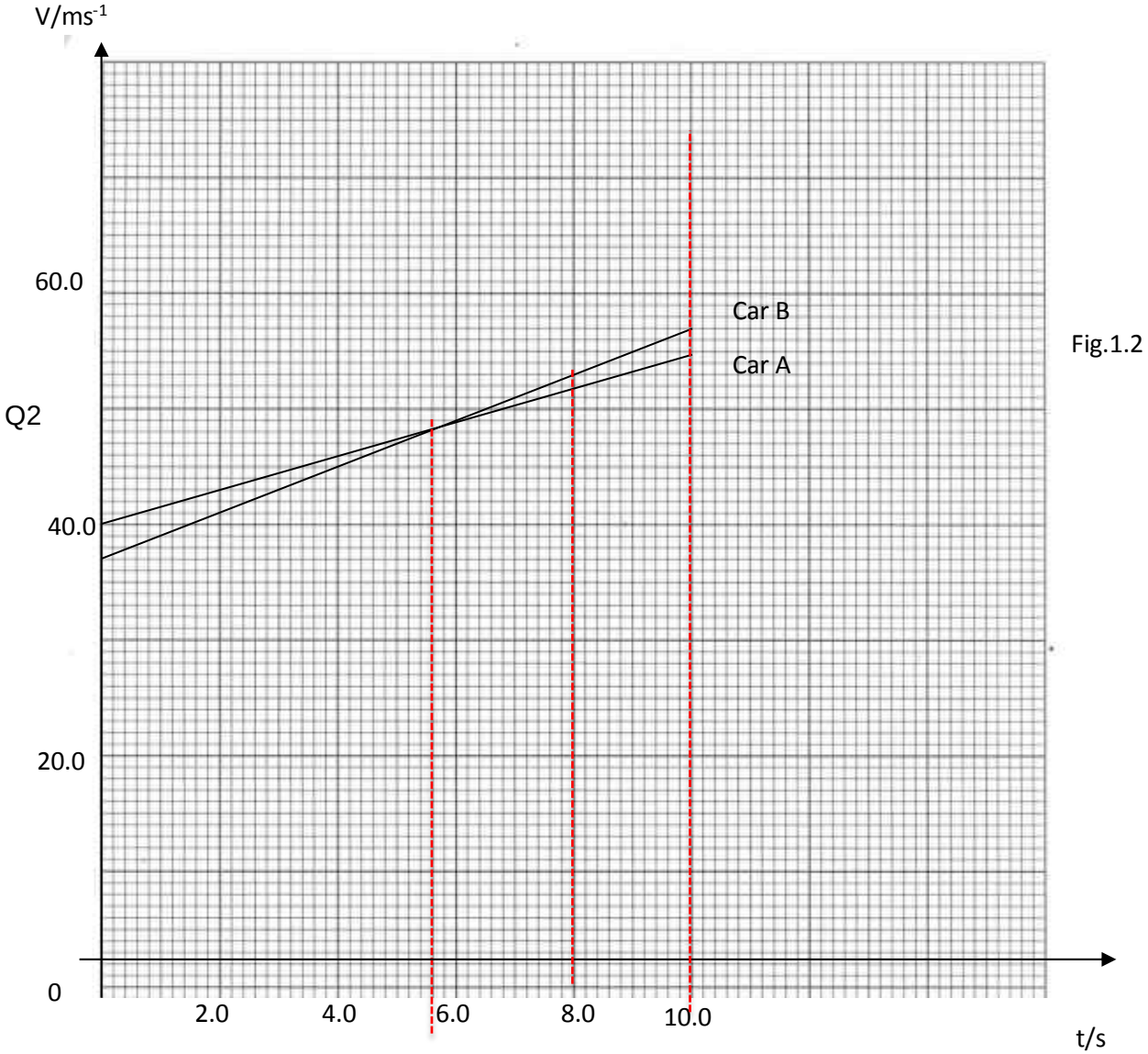


Fig.1.2

Q2

$V_A = 40 + 1.45\ (10) = 54.5\ ms^{-1}$

$V_B = 37 + 2.05\ (10) = 57.5\ ms^{-1}$

1(b)(iii) The area under the velocity-time graph will give the displacement of the car.

From the graph, at t = 8.0 s, the area under the graph of Car A is bigger than the area under the graph by Car B. From t = 0 to t = 5.4 s, Car A covered a larger distance. From t = 5.8 s to t = 8.0 s, Car B covered a larger distance. Comparing the 2 regions, area under the graph by car A is still more than shaded area B. Hence Car A has covered more distance than Car B at t = 8.0 s.

Or

The 2 cars' velocities are equal at t = 5.8 s. Car A is ahead of Car B. Hence for the displacement to be the same, Car B can only be together with Car A at t = 11.6 s. Hence at t = 8.0 s, car B will still be behind Car A.

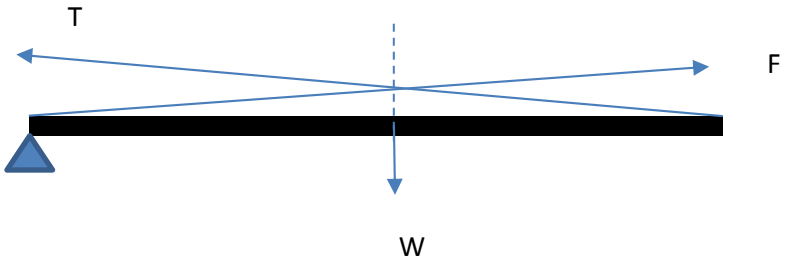
2(a)(i) Upthrust is a result of pressure difference in a fluid, due to height difference.

2(a)(ii) mg. Weight of the air inside the balloon is acting vertically downwards and is given by ρVg where V is the volume of the balloon.

The balloon will experience an upthrust in the vertically upwards direction. The magnitude of the upthrust is given by the weight of the air displaced by the balloon which is also ρVg, since the density of air is ρ and volume is also V. The 2 forces cancel one another and therefore the weighing scale gives only mg.

2(b)(i) Taking moments about the pivot, for equilibrium, the anti-clockwise moment due to T must be equal to the clockwise moment due to W. Since the perpendicular distance from the pivot to T is smaller than the perpendicular distance from W to the pivot, T must be larger than W.

2(b)(ii)

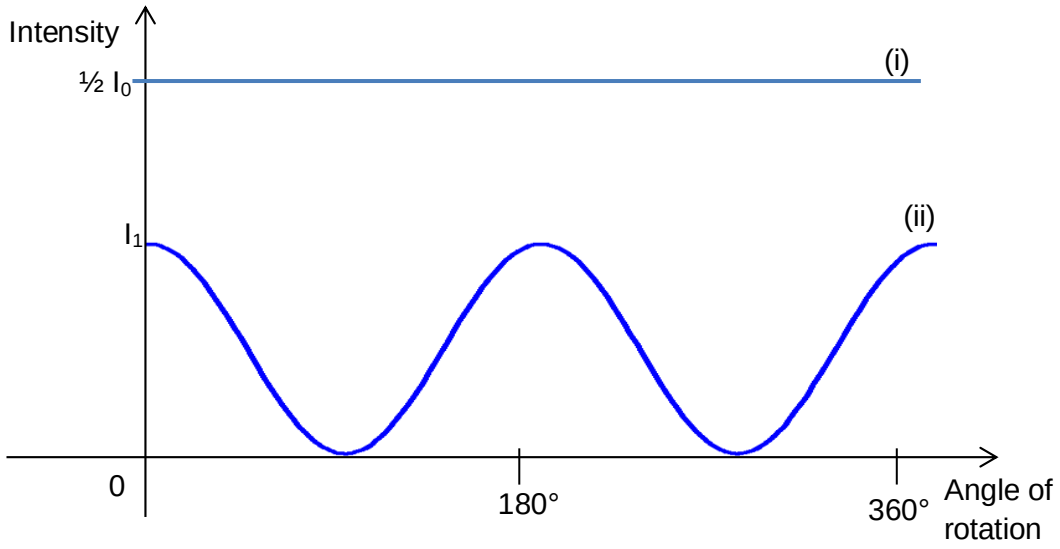


Three non-parallel forces acting on a body in equilibrium, 3 forces must pass through the same point in space. Taking moments about the end of rod, for equilibrium, the anti-clockwise moment due to W must be equal to the clockwise moment due to F. Since the perpendicular distance from the end of rod to F is smaller than the perpendicular distance from W to the end of rod, F must be larger than W.

3(a)(i) A plane polarised wave is one in which the particles' plane of vibration is fixed along a particular direction.

3(a)(ii) Sound waves are longitudinal waves. The direction of vibration of particles is parallel to the direction of travel of the wave and thus cannot be polarised. Only transverse waves can be polarised.

3(b)



3(c) Determine the highest order that can be seen on the screen,

$n_{max} \leq \frac{d}{\lambda}$

$n_{max} = 3$

1st order, wavelength = 589.59 nm, $\theta_1 = 17.15°$

1st order, wavelength = 589.99 nm, $\theta_{1'} = 17.16°$

3rd order, wavelength = 589.59 nm, $\theta_3 = 62.18°$

3rd order, wavelength = 589.99 nm, $\theta_{3'} = 62.25°$

The central maxima will be the brightest with both wavelengths combined. The highest order that can be seen on the screen is the third order. There will be a total of 13 bright fringes that will be seen including the central maxima.

4(a) From the graph, it is observed that V is inversely proportional to r and potential is defined to be zero at infinity. Values of V is negative as the charge is negative and thus work done to bring unit positive charge from infinity to the point is negative.

4(b)(i) Magnitude of electric field strength is the gradient(or slope) of the tangent or line drawn at that point.

4(b)(ii) At x = 0 cm, the electric force is the maximum (in positive x direction).
From x= 0 cm to 6.0 cm, the force decreases from a maximum value to zero at x=6.0 cm. From 6.0 cm to 10 cm, the force increases from zero with direction of force is in opposite direction, i.e negative x direction.

4 (c) As the positively charge particle moves from x=0 to x =10cm, it losses electric potential energy and gain kinetic energy.

By conservation of energy,

Loss in EPE = Gain in KE

$q(570 - 230) = ½ mv^2$

$v^2 = 2(q/m)340 = 2(4.8 \times 10^7)340 = 1.8 \times 10^5 \text{ ms}^{-1}$

5(a) By Fleming's Left Hand Rule, the direction of the force on coil XY by magnet is downwards. By Newtons's 3rd Law, the force acting on the magnet by coil is upwards. The reading on balance is measured by the normal contact force acting on magnet. Once the current is switched on, the normal contact force acting on magnet is reduced, i.e weight – magnetic force on magnet. Therefore, reading on scale decreases.

5(b)(i) F = NBIL

$F = 120 \times 0.45 \times 15 \times 10^{-3} \times 2x\pi \times 25 \times 10^{-3} = 0.127$ N

5(b)(ii) A fluctuating electric current flows through the coil.

Since the coil is perpendicularly to a magnetic field, it experiences a magnetic force and the magnitude of force is proportional to the current.

As the coil is attached to the speaker cone, the cone will oscillate with an amplitude that is proportional to the amplitude of current in coil.

6(a) **Existence of** λ_{min} - To produce an x-ray photon, the accelerating electron must decelerate suddenly when it collides with the target atom.

The minimum wavelength comes about when **100% of the kinetic** energy of a electron is **loss** and converted to a single x-ray **photon of maximum** energy.

X-ray continuous spectrum/braking radiation/Bremsstrahlung – To produce an x-ray photon, the accelerating electron must decelerate suddenly when it collides with the target atom.

The kinetic energy lost by the electron can be converted into any number of photons of different energies. The wavelength of each photon is longer than λ_{min} . Thus, a continuous spectrum is obtained.

Existence of peaks in the continuous X-ray line spectrum - A high speed electron collides and knock off an electron in an inner shell of the target atom, leaving a vacancy in the inner shell.

Electron from the outer shell (which is at a higher energy level) de-excite to fill up the vacancy in the inner shell.

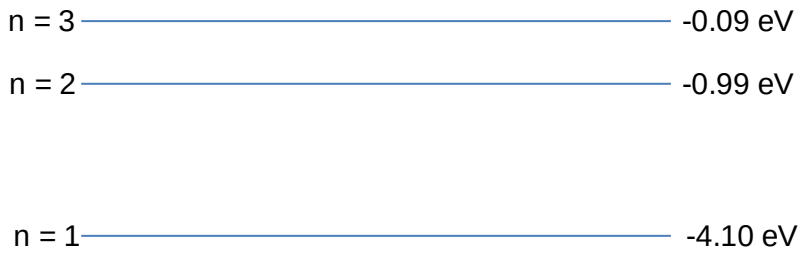
When the electron de-excite, the electron loses energy. The energy loss by electron is given out as a photon with energy equal to the energy difference between the outer and inner shells. Hence the line spectrum is unique to different target materials.

(Any 2 of the above)

6(b) λ1 = 310 nm, ΔE1 = 4.01 eV

λ2 = 400 nm, ΔE2 = 3.11 eV

λ3 = 1377.8 nm, ΔE3 = 0.90 eV



7(a)(i) $T = Kr^{m/n}$

Rearranging, $K = T/r^{m/n}$

For values of T and r, the theory is valid if K is a constant.

Using the data from the table:

Moon	T/days	$r/10^8$ m	K
Metis	0.295	1.28	2.037×10^{-13}
Europa	3.55	6.71	2.042×10^{-13}
Callisto	16.7	18.8	2.048×10^{-13}

K is approximate constant with a value of 2.04×10^{-13}.

7(a)(ii) Lg (r/ m) = 8.625

Lg (T/s) = 0.248

Point (8.63, 0.25) to half the smallest square division

7(a)(iii) Gradient = [1.22-(-0.530)]/ [9.27-8.11]

= 1.75/1.16

= 1.51 = 1.5 (2 sf)

7(a)(iv) From 7(a)(i), $T= kr^{m/n}$

Linearizing: Lg T = (m/n) lg r +lg k

From fig 7.2, a straight line graph with a negative y-intercept is obtained with a gradient equals to 1.5. Hence the data fits the equation given by the theory.

7(a)(v) Based on the predicted gradient, m/n = 1.5 hence if m and n are integers,

m = 3, n = 2

7(a)(vi) Using lg (r/m) = 9.27 and lg (T/days) =1.22

T = 16.6 days = 1.434×10^6s

Lg (T/s) = 6.16,

6.16 = 1.5 (9.27) +lg k

$K = 1.80 \times 10^{-8}$

$1.80 \times 10^{-8} = \sqrt{(4\pi^2/GM)}$

$M = 1.83 \times 10^{27}$ kg

7(b)(i)1. Intensity on earth, $I = P_s/4\pi r^2$ where P_s = Power of the sun

$1400 = P_s/ 4\ \pi r^2$ …..[1]

Intensity on Jupiter, $I' = P_s/ 4\ \pi(5.2)r^2$ ……[2]

Eqn [2]/Eqn [1]: I = 51.8 W which is close to 50 W

7(b)(i)2. Intensity received by Juno's spacecraft = I'

$I' = P_r/A$ where P_r = Power received by the solar array.

51. 8 = P_r/60

P_r = 3102 W

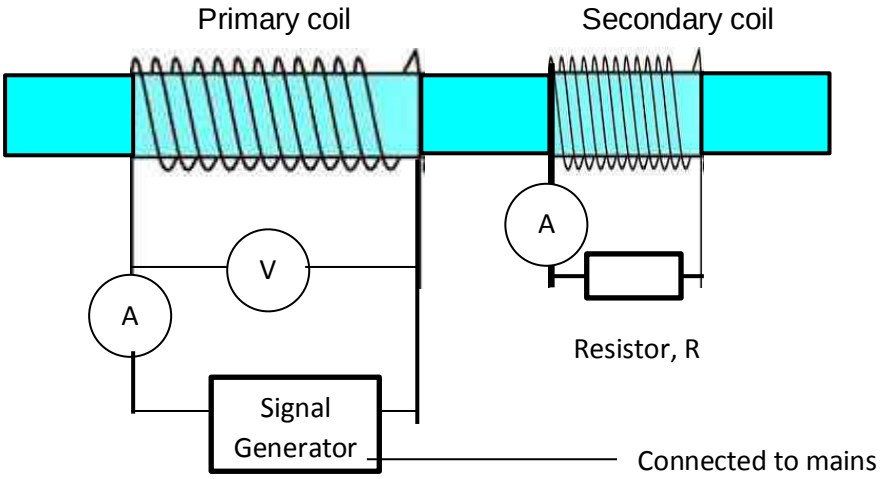
Efficiency = 500x100%/3107 = 16.1%

7(b) (ii) High speed electrons produces x-rays which may be harmful to the electronics systems in the space craft.

High speed electrons will knock out electrons in the atoms of the electronics components thereby damaging the spacecraft's system.

8

Diagram



Independent variable: frequency of the power supply, f_{in}
Dependent variable: efficiency of transformer, E
Fixed variables: the voltage of the input power, no. of coils of primary and secondary coils, Distance between the coils

Procedure:

1. Set up the rest of the apparatus as shown in the diagram above.
2. Switch on the signal generator, and set it to suitable frequency.

Measuring the variables

3. Record the input voltage V_{in} and input current I_{in} in the primary coil from the digital voltmeter and ammeter respectively.
4. Record the output I_{out} in the secondary coil from the digital ammeter.
5. Read and record the value of input frequency f_{in} from the signal generator.

Calculation of data:

6. Calculate efficiency of the transformer using $E = I_{out}^2 R / V_{in} I_{in}$

Varying the independent variable:

7. Vary the input frequency to the primary coil by increasing the frequency through the signal generator by 10 Hz.

Repeating the experiment:

8. Repeat step 3 – 7 to obtain 10 sets of readings.

Analysis of data:

9. Tabulate the values of f_{in}, V_{in}, I_{in}, V_{out}, I_{out}, P_{in}, P_{out} and E.
10. The relationship of the independent variable and the dependent variable is assumed to be of the form $E = k f_{in}^n$, where k and n are constants.
11. Plot a graph of lg E vs lg f_{in}. If a straight line is obtained from the graph, determine the gradient of the line which is n. Equate lg k to the vertical-intercept. Then determine k. Hence the relationship of E and P_{in} can be deduced.

Safety Precaution:

- Ensure that the iron core and coils are well insulated to ensure that the experimenter do not get an electric shock. Alternatively wear insulated gloves when conducting the experiment.
- Do not perform the experiment for voltage more than 20 V to prevent overheating.

Additional details:

- The apparatus should also be allowed to cool down before performing each set of experiment to keep heat loss during experiment to a minimum.
- Conduct preliminary trials of the experiment to find the suitable range of input frequencies.
- Magnetic shielding should be provided to ensure that the magnetic field through the simple transformer is not affected by other sources.
- Detailed explanation of how to keep voltage of input power or distance between the coils fixed.

Paper 3

1(a)(i) Now consider a body of mass *m* at rest brought to velocity *v* over a distance *s* by a constant force *F*.

The final velocity *v* is given by $v^2 = u^2 + 2as$,

where *a* is constant acceleration given by $a = \frac{F}{m}$.

We have $v^2 = u^2 + 2\frac{F}{m}s$.

Rearranging, $\rightarrow F\,s = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

The change in Kinetic Energy of an object equals the net work done on the object.

Since the body starts from rest ($u = 0$), its final kinetic energy of body = work done on body by *F* = $E_k = \frac{1}{2}mv^2$.

1(a)(ii) Since the speed is constant, the change in KE is zero. Hence, by COE, the chemical energy is all used to do work against air resistance and thus no such transformation taking place.

1(b)(i) P = W/t

36.6×10^3 = W/300, W = 1.1×10^7 J

1(b)(ii) Not worth, since the KE =3.46×10^5 J even when it is moving at 31 ms^{-1} and thus will be even lower when it slows down. Hence, since the KE will be so much lower than the WD against the resistive force, a large part of the energy would still be provided by the fuel of the car.

2(a) Consider a collision that occurs when A collides with B in a straight line. By Newton's second law the change in momentum for A, $\Delta p_A = F_{BA} * \Delta t$, where F_{BA} is the force B exerts on A and Δt is the duration the force is exerted while the change in momentum for B, $\Delta p_B = F_{AB} * \Delta t$, where F_{AB} is the force A exerts on B.
By Newton's third law, $F_{BA} = -F_{AB}$ since they are an action-reaction pair.
Hence, $\Delta p_A = -\Delta p_B$.
This implies $p_{AF} - p_{AI} = -(p_{BF} - p_{BI})$, where p_{AF} is the final momentum of A, p_{AI} is the initial momentum of A, p_{BF} is the final momentum of B and p_{BI} is the initial momentum of B.
Rearranging, $p_{AI} + p_{BI} = p_{AF} + p_{BF}$. This implies the total initial momentum is the same as the total final momentum if no external force acts on this system.

2(b)(i) The total initial momentum of the system is zero. Hence the total final momentum is zero, implying that the final momentum of magnet A = -(final momentum of magnet B). If the mass of both magnets are the same, then the final velocity of magnet A = -(final velocity of magnet B).

2(b)(ii) Work was done on both magnets since an external force was applied to oppose the repulsive magnetic force between the two magnets. This was stored as potential energy between the two magnets resulting in an increase in kinetic energy when the external force was removed.

2(c) At the top of the track, Fnet = 3mg + N.
To determine the minimum velocity to keep in contact, Fnet = 3mg
Fc = $\frac{3mv_{min}{}^2}{r} = 3mg$
$v_{min}{}^2 = \sqrt{rg}$
Applying conservation of energy,
Total energy at the top of the track = Total energy at the bottom of the track
$\frac{1}{2}mv_{min}{}^2 + mg(2r) = \frac{1}{2}mv_B{}^2$
$v_B = \sqrt{5rg}$
Assumption: The track is frictionless so that no net external force acts of the system.
Applying principle of conservation of linear momentum,
$mv_0 = 3m\sqrt{5rg}$
$v_0 = 3\sqrt{5rg}$

3(a)(i) As point X is adjusted in the direction of B, the potential difference (p.d) across AX will vary. There will be a point along AB where by the p.d across AX will be equal to the e.m.f of the driven cell.
When this happens, no current will flow in the lower circuit, thereby showing a null reading on the galvanometer.

3(a)(ii) The e.m.f of the driver cell is smaller than the e.m.f of the driven cell. The p.d across the driven cell will always be greater than p.d across AX and thus the current will always flow in one direction. No null deflection will be detected.
Balance length L = 0.2 cm
Uncertainty in measurement of balance length = 0.2 cm

3(a)(iii) The balance length AX is too small to be reliable and accurate in reality. {1}
Percentage uncertainty will be large as the value of the value of the balance length approaches the value of the uncertainty of the measurement of the balance length. {1}
For example.
1 v = k 100
$2x10^{-3}$ v = k L
Balance length L = 0.2 cm
Uncertainty in measurement of balance length = 0.2 cm
Percentage uncertainty = 0.2/0.2 x100 = 100%

3(b)(i) 1.02 V

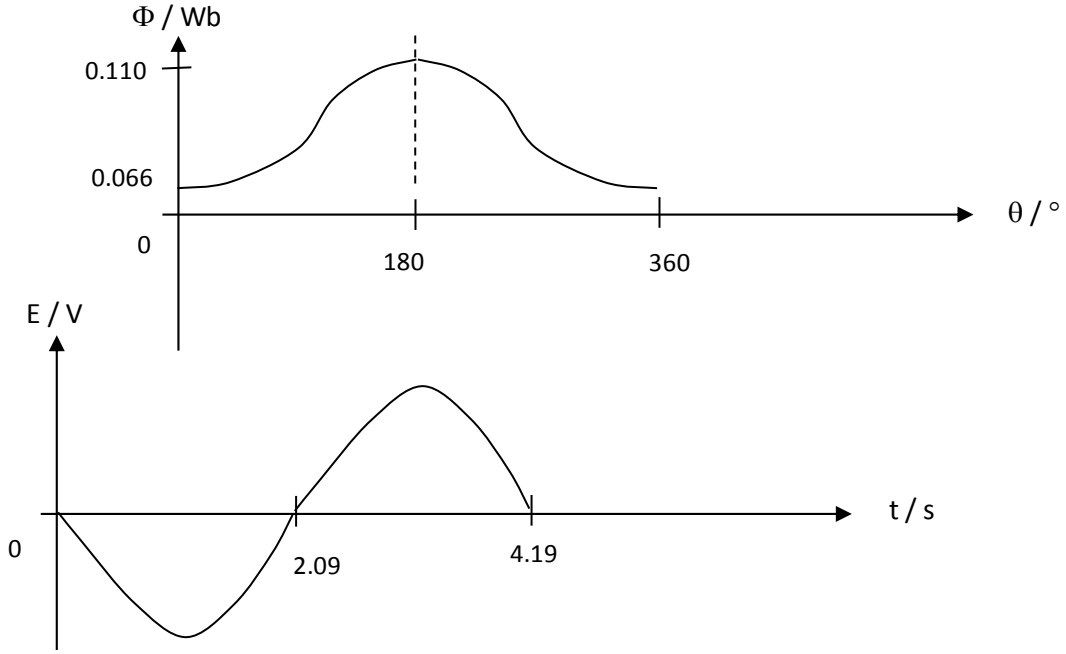
3(b)(ii) Let the balance point be X.
Resistor across balance length CX = (79/100) x 2.00 = 1.58 Ω
Total Resistance of the circuit = R_{total}
$V_{AB} = (R_{AB}/R_{total}).E$
$1.02 = (102/R_{total}).E$ ….[1]
$V_{CX} = (1.58/R_{total}).E$ …. [2]
Eqn [2]/ Eqn [1] : Vcx = [1.58/102] x 1.02 = 0.0158 V

4(a) Magnetic field B = $\frac{\mu_0 NI}{l} = \frac{4\pi\times10^{-7}\times500\times0.50}{0.10}$ = 3.14 × 10^{-3} T
Magnetic flux Φ= BA = $3.14 \times 10^{-3} \times 1.6 \times 10^{-4}$ = 5.02 × 10^{-7} Wb

4(b)(i) Change of Φ = $V\Delta t = 2.0 \times 10^{-3} \times 0.20 \times 10^{-3} = 4.0 \times 10^{-7}$ Wb

4(b)(ii) Final flux through loop = $(5.0 \times 10^{-7}) - (4.0 \times 10^{-7}) = 1.0 \times 10^{-7}$ Wb
Since cross sect A is constant, magnetic flux is proportional to current.
Since magnetic flux is reduced by 5 times, the current has decreased to 1/5 of original.
I = 0.10 A

4(c)(i)



5(a) Electrons in the n-type semiconductor diffuse across the junction to the p-type semiconductor due to higher concentration gradient. This is Vice-versa for holes from p-type to n-type)

The electrons and holes will recombine and the region will be depleted of mobile charged carriers and will leave behind immobile charged ions.

At equilibrium, the electric field set up in the depletion region will be strong enough to prevent more electrons/ holes from diffusing across from the n-type to the p-type semiconductor or p-type to n-type semiconductor respectively.

The potential difference due to this electric field within the depletion region can be thought of as a “potential energy barrier” that prevents the further migration of electrons across the junction.

5(b) (i) forward bias

5(b)(ii) When the p-type semiconductor is given a higher applied potential relative to the n-type semiconductor, the applied electric field opposes the original E-field within the depletion region. This causes the resultant electric field strength and the corresponding potential difference within the depletion region to decrease. When the applied electric field is strong enough, the potential energy barrier will be removed and a net current flows in the circuit.

OR

In forward bias connection, the width of the depletion region decreases because the electrons in the n-type semiconductor are pushed away from the negative end of the p-n junction into the depletion region while the holes are pushed away from the positive end of the p-n junction into the depletion region.

6(a) Frequency *f* of a body undergoing simple harmonic motion is the number of complete oscillations that the body undergoes per unit time.
Angular frequency ω of the same body is related to *f* by a factor of 2π i.e. $\omega = 2\pi f$.
The angle of 2π is associated with one complete cycle of oscillation

6(b) For a motion to be in simple harmonic motion, the acceleration, a must be directly proportional to displacement, x and the direction of acceleration must be in opposite direction of the displacement [1], i.e $a = -\omega^2 x$ (or $a = -kx$, k is constant) where ω is a constant(angular velocity).
Displacement of shadow, $X = R\sin\phi$

$= R\sin\omega t$ where $\phi = \omega t$,

ω is angular velocity, t is the time.

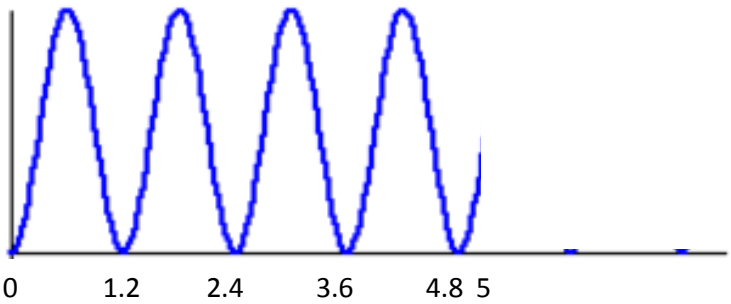
Acceleration of shadow, $a = \frac{d^2X}{dt^2} = -\omega^2 R\sin\omega t$

$a = -\omega^2 X$, since $X = R\sin\omega t$

Therefore, the motion of shadow is simple harmonic motion.

6(c)(i) Maximum velocity is reduced since amplitude is reduced.
Max KE is reduced to one quarter of its initial maximum kinetic energy (or 4 times smaller).

6(c)(ii)



Period is 2.4s, shape
Note: student must sketch the graph up to t = 5.0s

6(d) Photoelectric effect has taken place, negatively charged electrons are emitted out from Barium, Barium acquired positive charged.

6(e) The incident photon will be absorbed by the electron if its energy is greater than work function of metal.
Since there is no accumulation of energy through absorption of multiple photons, there is no time delay in the emission of photoelectrons.

6(f) It shows the existence of <u>discrete energy levels</u> in hydrogen atoms. The electromagnetic radiation or photon energy occurs at certain (or discrete) frequencies, the energy levels in atoms are discrete (or quantised).
The electron in the atom de-excites from the higher energy state to a lower energy state, it will emit a photon with energy equals to the difference in the energy levels.

6(g) The electron at <u>the metal surface require the least amount of energy to be emitted, hence it has maximum kinetic energy</u>.
Electrons that are not directly below the surface require energy to bring it to surface, so less kinetic energy.
Hence, there is a range of kinetic energy up to a maximum value for the electrons.

6(h)(i) In a crystalline solid, the regularly arranged atoms (or the atomic spacing between the atoms is constant) acts like a diffraction grating.

6(h)(ii) The electrons behave as a wave since electron diffraction take place. Electrons are accelerated and gained kinetic energy. Only electrons of suitable kinetic energies ($E_k = \frac{p^2}{2m_e}$) have momentum and the de Broglie wavelength, i.e. p = $\frac{h}{\lambda}$ associated with this momentum is of the same order of magnitude as the atomic spacing, i.e 10^{-10}m.

7 (a) Considering 1 mole of gas of volume V_R,
$V_R = M_R / \rho$
$PV = nRT$
$P (M_R / \rho) = (1) RT$
$P = \rho RT/M_R$ (shown)

7(b) (i) $P = \rho RT/M_R$
At sea level, h = 0 m,
$P_0 = 100 \times 10^3 = (1.3) RT / M_R$ ----- (Eqn1)
At h = 8.0 km
$P_8 = 35 \times 10^3 = \rho_8 RT/ M_R$ ----- (Eqn2)
(Eqn2)/(Eqn1),
$(35 \times 10^3)/(100 \times 10^3) = \rho_8 / 1.3$
$\rho_8 = 0.455$ kg m^{-3}

7(b)(ii) $P_8 = 0.3 P_0$
$\rho_8 R (273.15 – 23) / M_R = 0.3 (1.3) R (273.15 + 20) / M_R$
$\rho_8 = 0.457$ kg m^{-3}

7(b)(iii) The specific latent heat of varporisation will decrease as the pressure at the summit of Mt Everest is smaller hence there is less work done by the water as it expands. The amount of energy required by the system to overcome intermolecular forces will remain similar to that at the sea level.

Note: The ***boiling point*** of a substance is the temperature at which the vapor ***pressure*** of the liquid equals the ***pressure*** surrounding the liquid and the liquid ***changes*** into a vapor. The ***boiling point*** of a liquid varies depending upon the surrounding environmental ***pressure***.

7(c)(i) Wave travel down the tube and gets reflected by the water.
The incident and the reflected waves, both having the same amplitude, frequency(or wavelength) and speed travelling in opposite directions superpose to form standing wave.

OR

The incident sound wave travels along the tube and is reflected by the water.
The superposition of the incident and reflected wave of same amplitude, speed and wavelength(or frequency) but travelling in opposite directions creates a standing wave in the pipe.

7(c)(ii) Air column in tube has natural frequency of vibration
When fork frequency is equal to natural frequency of vibration of air column in tube, resonance occurs; there is maximum energy transfer and maximum amplitude of vibrations occurs, leading to maximum loudness.
When fork frequency is not equal to natural frequency, no resonance occurs and loudness drop.

7(c)(iii) $\frac{\lambda}{4} = L_1 + c$ ----------(1) c is the end correction

$\frac{3\lambda}{4} = L_2 + c$ ----------(2)

(2) – (1) $\Rightarrow \frac{1}{2}\lambda = L_2 - L_1 = 32.4$ cm

$\Rightarrow \lambda = 64.8$ cm

$v = f\lambda = 512 \times 0.648 = 332$ m s^{-1}

7(c)(iv) $\frac{1}{4}\lambda = L_1 + c = 15.7 + c \Rightarrow c = \frac{1}{4} \times 64.8 - 15.7 = 0.50$ cm

Therefore, antinode is 0.50 cm above the top of the tube OR antinode is 16.2 cm above water surface.
There is a presence of end correction. The region of lowest pressure is not at the mouth of the tube but is actually a distance away from end of tube.

8(a)(i) The majority of the alpha particles pass though the gold foil undeflected.

8(a)(ii) A handful of alpha particles reflected in the opposite direction.

8(b)(i) Nuclear fusion refers to the ***combination*** **of** ***lighter*** **nuclides** to form heavier, more stable nuclei, releasing energy in the process.
OR
The building up of a larger nucleus from two nuclei of low nucleon number, with the release of energy.

8(b)(ii) Total mass of constituents = 12.099 u > 12 u. As energy will be absorbed (binding energy) when the nucleus break up, by Albert Einstein's Mass-Energy Equivalence, there will be a corresponding gain of mass ($\Delta E = \Delta mc^2$) called the mass defect. Hence, the mass of constituents will be larger.

8(b)(iii)(1) Energy released = $BE_{pdt} - BE_{rxn}$ = 90(8.5)+ 144(8.5) – 235(7.5)
=226.5 MeV = 3.62×10^{-11} J

8(b)(iii)(2) Kinetic energy of product and gamma ray photons.

8(c)(i) Random means in any sample of a radioactive material, it is not possible to predict which nucleus will decay next and thus the decay appears randomly throughout the sample.
Spontaneous means that is unaffected by environmental factors such as temperature and pressure.

8(c)(ii) The random nature would imply that there will be a lot of fluctuations in the readings of the count rate. Hence, the best-fit curve would subject to a lot of uncertainty and thus the half-lives would have a large error.

8(c)(iii) Initial count = 60 s^{-1}
Background count = $8s^{-1}$
Hence, mean half-life = (65s + 70)/2 = 67.5 s

8(c)(iv) Only lead could absorb γ-ray photons and thus could prevent harmful radiation from leaking.
The lead will be hot after absorbing the γ-ray photons and thus need polystyrene to act as heat insulator.

8(d) After 3 half-lives, the count rate would be 120 s^{-1}. But the mass of iron would be reduced by to ¼ of the original mass.
But, count rate α mass of iron
Hence, count rate would be $30s^{-1}$

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

PHYSICS

9646/01

Paper 1 Multiple Choice

28 September 2016

1 hour 15 minutes

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 **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 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.

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	=	$-Gm / r$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{1/2}}$

1 The magnetic flux density B on the axis of a long solenoid is given by $B = \mu_0 nI$ where n is the number of turns per unit length, I is the current in the solenoid and $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}.

Which of the following are the base units of henry, H?

A kg m s^{-2} A^{-2} **B** kg m^2 s^{-2} A^{-2} **C** kg m s^{-2} A^{-1} **D** kg m^2 s^{-2} A^{-1}

2 Two playground swings start out together. After 10 complete oscillations, the swings are out of step by half a cycle. Given that the period T of the swing is related to the length L by the expression $T = 2\pi\sqrt{\frac{L}{g}}$, what is the percentage difference in the lengths of the swings?

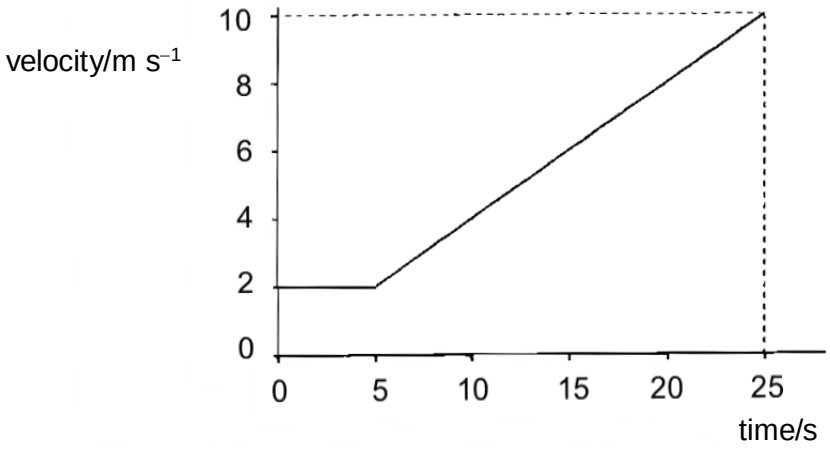
A 1% **B** 2.5% **C** 5% **D** 10%

3 A man throws a ball vertically upwards. The ball travels 25% of the total distance from the hand to the maximum height in the last second of its ascent.

What is the time of the ascent given that the effects due to air resistance are negligible?

A 1.25 s **B** 1.50 s **C** 1.67 s **D** 2.00 s

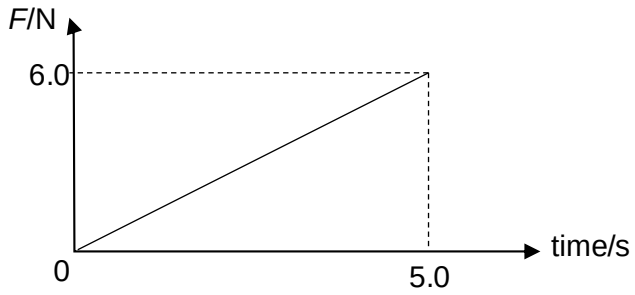
4 The diagram shows a velocity-time graph for a particle moving along a straight line.



What is the average acceleration of the particle between 0 s and 25 s?

A 0.20 m s^{-2} **B** 0.32 m s^{-2} **C** 4.0 m s^{-2} **D** 5.2 m s^{-2}

5 When a force F, varying as shown below, is applied in the opposite direction to a mass of 10 kg moving with a velocity of 2.0 m s^{-1}, the final velocity of the mass at the end of 5.0 s is



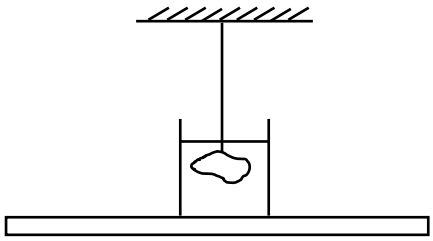
A –1.0 m s^{-1} **B** –0.5 m s^{-1} **C** 0.5 m s^{-1} **D** 1.0 m s^{-1}

6 A body, initially at rest, explodes into two fragments of masses M and $3M$ having total kinetic energy E.

What is the kinetic energy of the fragment of mass M after the explosion?

A $\frac{E}{4}$ **B** $\frac{E}{3}$ **C** $\frac{2E}{3}$ **D** $\frac{3E}{4}$

7 A stone, suspended from a string, is fully immersed in a beaker of water as shown below. The force which forms an action-reaction pair with the weight of the stone is



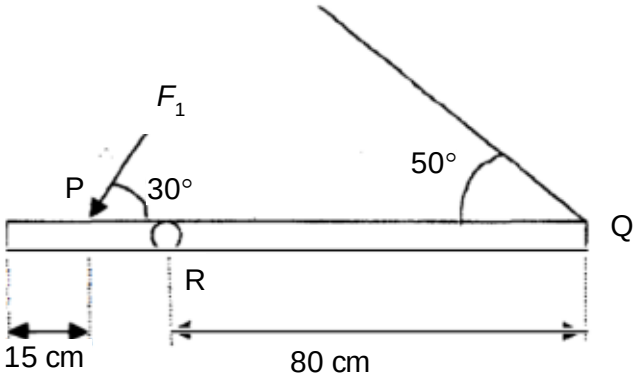
A the tension in the string.

B the upthrust on the stone.

C the sum of the tension in the string and the upthrust on the stone.

D the gravitational pull of the stone on the Earth.

8 A uniform rod of length 1.0 m and weight *W* is freely hinged at R. It is held in equilibrium by a light inextensible string at point Q and a force F_1 is applied at P as shown. If F_1 is $W/2$, what is the tension of the string at point Q?



A 0.47 *W* **B** 0.65 *W* **C** 0.75 *W* **D** 0.90 *W*

9 A small metal sphere of mass *m* is falling vertically through a viscous fluid. When it reaches a constant velocity *v*, which of the following statements is false?

A The kinetic energy is constant and equal to $\frac{1}{2}mv^2$.

B The gravitational potential energy decreases at a rate of *mgv.*

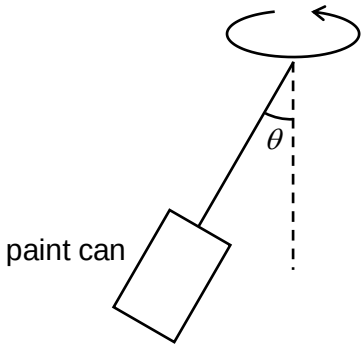
C The total mechanical energy of the sphere is constant.

D The resistive force acting on the sphere is constant.

10 A baseball pitcher throws a baseball of mass 145 g with a speed of 40 m s^{-1} at an angle to the horizontal such that it reaches a maximum height of 15 m above the ground. Considering the motion of the baseball from the point of release to the peak of the trajectory, which of the following is correct?

	work done by gravity/J	change in kinetic energy/J
A	21	116
B	–21	95
C	21	–21
D	–21	–21

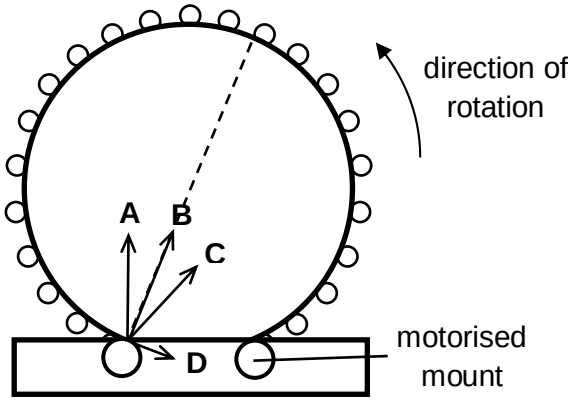
11 A paint can at an art installation is swung in a circle as it drips paint onto a canvas, as shown below.



After a period of time, the mass of paint in the paint can has decreased by 20%. If the angle of tilt θ remains unchanged and the paint can has negligible mass, what is the percentage change in the angular velocity?

A 0% **B** 11% **C** 20% **D** 45%

12 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?

13 Assuming the Earth to be a uniform sphere rotating about the axis through the poles, the apparent weight of a body at the Equator compared with its apparent weight at a pole would be

A smaller, because the gravitational attraction of the Earth must provide the weight and the centripetal force due to the circular motion of the body.

B the same, because the weight is the gravitational attraction of the Earth and for a uniform sphere, even when rotating, this is independent of the body's position on the Earth.

C greater, because the weight at the Equator is given by the sum of the gravitational attraction of the Earth and the centripetal force due to the circular motion of the body.

D greater, because the angular velocity of the Earth is greater at the Equator than at a pole.

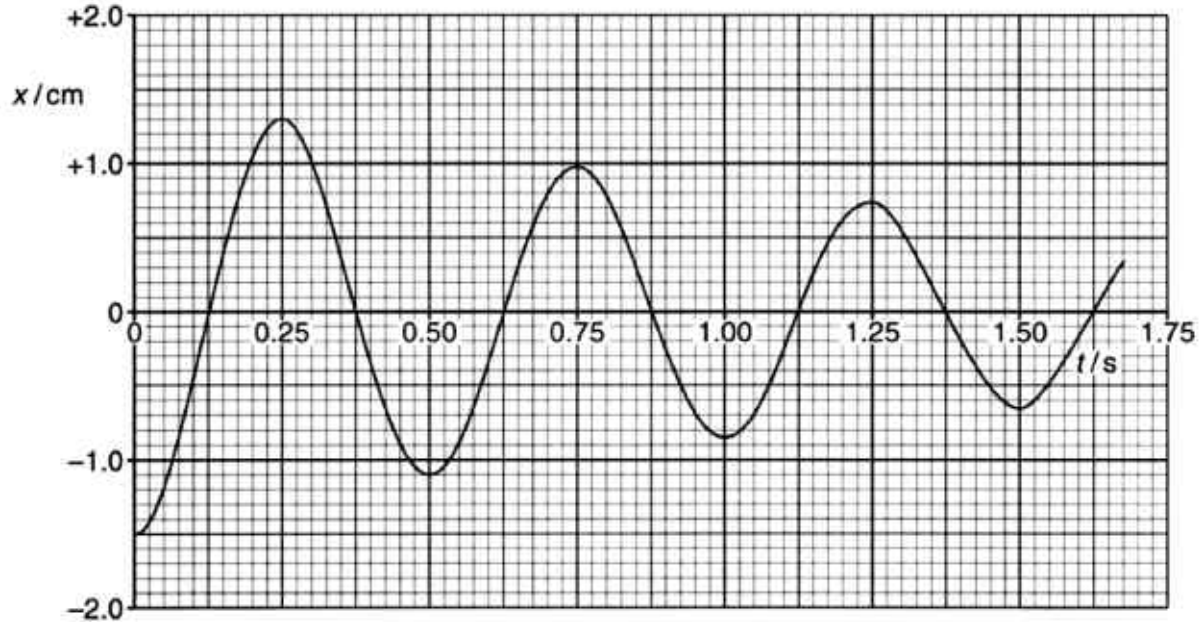
14 The table below gives the gravitational potential values at various points in the field of a planet in a planetary system.

distance from surface/km	potential/kJ kg^{-1}
0	–1141.6
220	–369.2
230	–345.8
240	–322.5
infinity	0

What is the gravitational acceleration at a height of 230 km on this planet?

A 1.50 m s^{-2} **B** 2.34 m s^{-2} **C** 3.46 m s^{-2} **D** 9.81 m s^{-2}

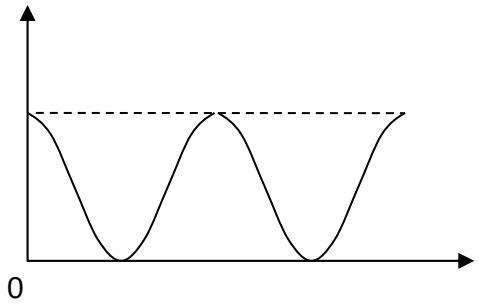
15 A coconut of mass 500 g floats on water and oscillates vertically. Its vertical displacement x varies with time t as shown.



What is the decrease in energy of the oscillations during the first 1.5 s?

A 2.9×10^{-3} J **B** 4.6×10^{-3} J **C** 7.2×10^{-3} J **D** 7.2×10 J

16 The diagram shows one possible graph for an object undergoing simple harmonic motion.



Which quantities must have been plotted to produce this graph?

A velocity and displacement
B kinetic energy and displacement
C potential energy and time
D insufficient information to conclude

17 Two containers of volumes 4.0 m^3 and 6.0 m^3 contain an ideal gas at pressures of 100 Pa and 50 Pa respectively. Their temperatures are equal and they are joined by a tube of negligible volume. The gas flows from one container to the other with no change in temperature.

What is the final pressure?

A 70 Pa **B** 75 Pa **C** 80 Pa **D** 150 Pa

18 An ideal gas gives off 1500 J of heat and contracts under a constant pressure of 1.5×10^5 Pa from a volume of 0.050 m^3 to 0.035 m^3.

What is the change in internal energy of the ideal gas?

A increase by 750 J
B increase by 3750 J
C decrease by 750 J
D decrease by 3750 J

19 The intensity of a wave depends on the amplitude and is also proportional to the square of the frequency.

A wave has frequency 3.0 Hz, amplitude 1.5 cm and intensity *I*.

What is the intensity of a similar wave of frequency 6.0 Hz and amplitude 0.5 cm?

A $\frac{4}{9}I$ **B** $\frac{4}{3}I$ **C** $\frac{9}{4}I$ **D** $36I$

20 Which of the following is true for all transverse waves?

A They are all electromagnetic.
B They can all be polarised.
C They can all travel through a vacuum.
D They all involve the oscillation of atoms.

21 Two identical waves with a phase difference of $\frac{\pi}{6}$ interfere giving rise to a resultant wave.

What is the ratio of the intensity of the resultant wave to the individual wave?

A 0.27 **B** 1.9 **C** 3.0 **D** 3.7

22 What is not an essential condition for an observable interference pattern to occur between the waves from two sources?

A The frequencies of the two sources must be equal.

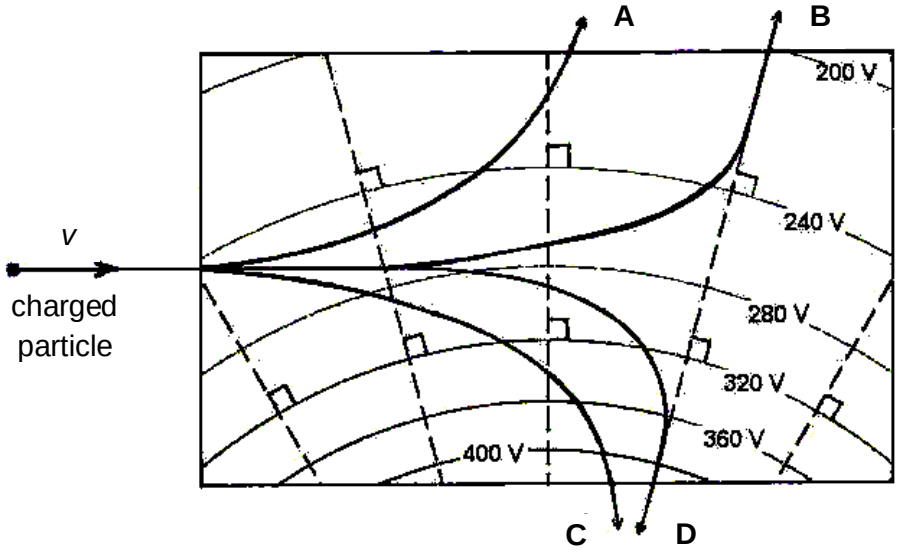
B The sources must be coherent.

C The sources must emit waves of equal amplitude.

D The waves from the two sources must overlap.

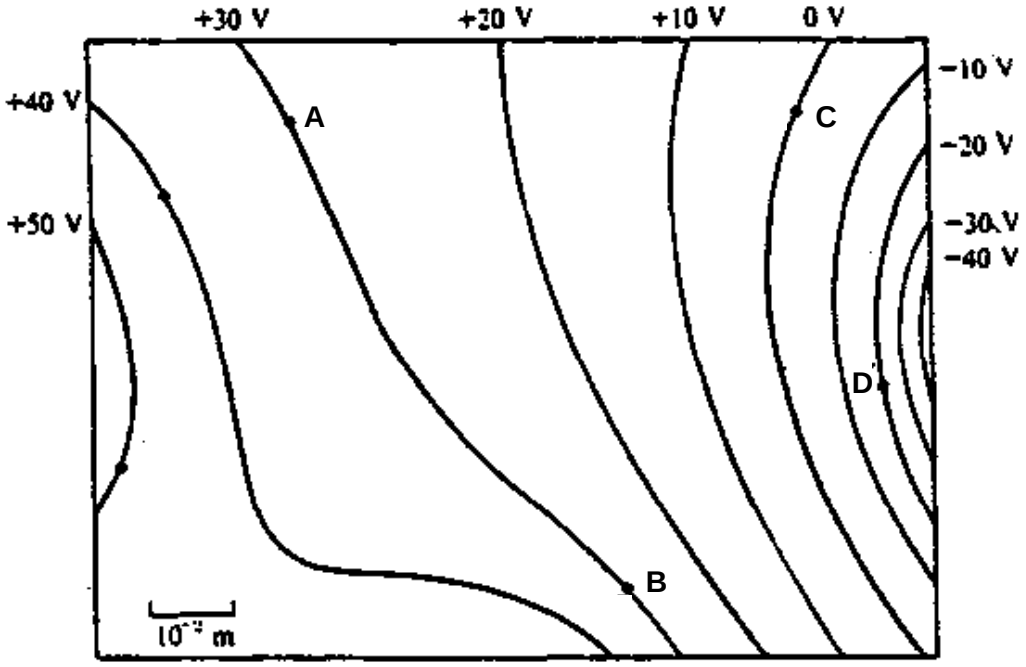
23 A negatively charged particle enters a region of non-uniform electric field whose electric potential varies as shown in the diagram.

Which is the most probable path of the charged particle in the electric field?

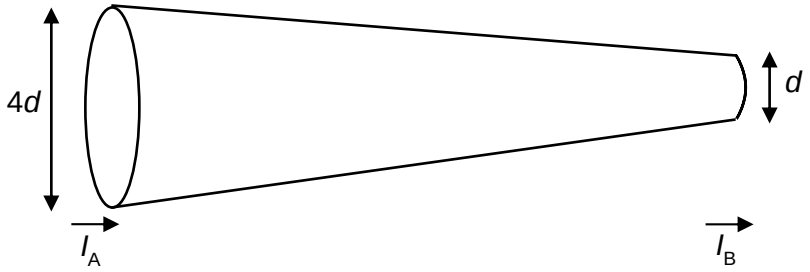


24 The diagram below is a scaled drawing showing the equipotential lines in the region of an electric field.

At which point does a charged particle experience an electric force of the greatest magnitude?



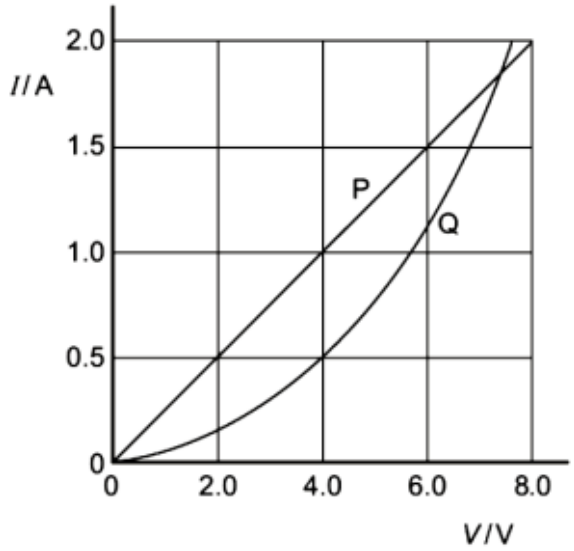
25 An electrical conductor has a shape as shown in the figure below.



The conductor is connected in series with a d.c. supply. What is the ratio of I_A to I_B?

A 1 **B** 2 **C** 4 **D** 16

26 The *I*-*V* characteristics of two electrical components P and Q are shown below.



Which statement is **incorrect**?

A P is a metallic conductor (resistor) and Q is a thermistor.

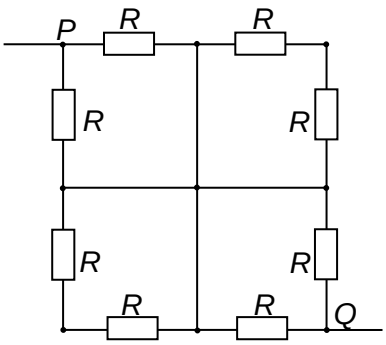
B The resistance of Q decreases as the current in it increases.

C At 1.9 A the resistance of Q is smaller than that of P.

D At 0.5 A the power dissipated in Q is double that in P.

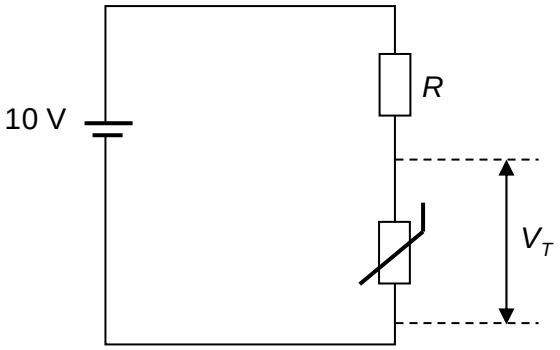
27 Eight identical resistors, each of resistance *R*, are connected in a network as shown below.

What is the effective resistance between the terminals P and Q?



A $\frac{R}{4}$ **B** $\frac{R}{2}$ **C** R **D** $2R$

28 A thermistor is connected in series with a fixed resistor of resistance R and a cell of e.m.f 10 V, as shown in the diagram below.



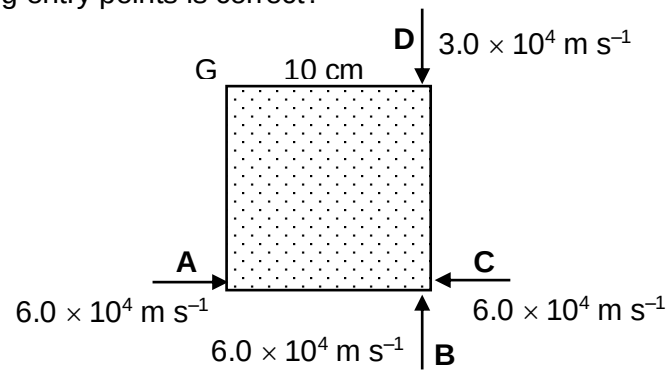
When the temperature of thermistor is 20 °C, its resistance is 5.3 Ω and the potential difference V_T across it is 4.5 V.

What is the value of V_T if the temperature of thermistor increases to 60 °C and the resistance drops to 3.1 Ω?

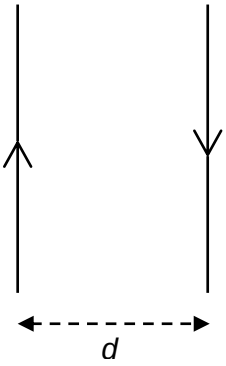
A 1.5 V **B** 2.6 V **C** 3.2 V **D** 3.5 V

29 The figure shows a square magnetic field of magnetic field density 3.5×10^{-6} T pointing out of the plane of the paper. An electron was observed emerging from the square magnetic field near corner G.

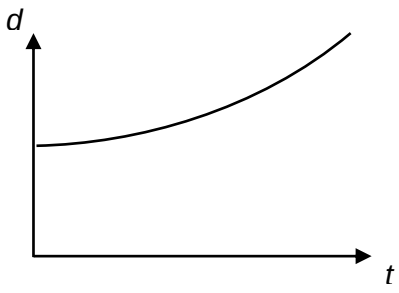
Which of the following entry points is correct?



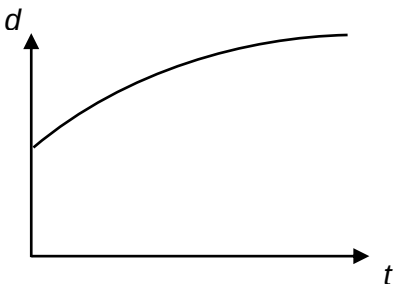
30 Two current-carrying wires are placed next to each other as shown. Both wires are unsecured and free to move. Which of the following graphs shows the variation with time *t* of distance between them, *d*?



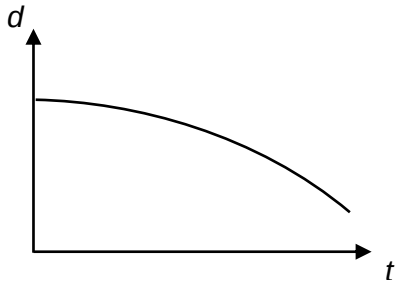
A



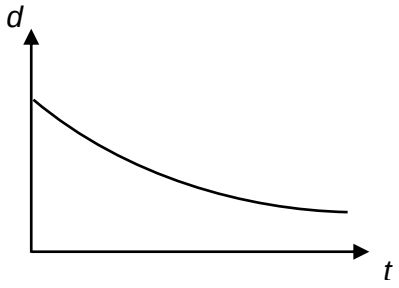
B



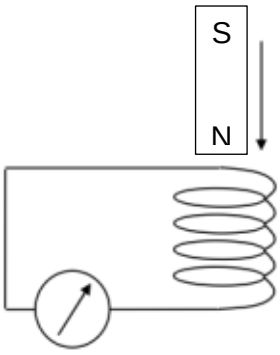
C



D



31 A bar magnet is dropped vertically above a coil that is connected to a galvanometer. As the magnet approaches the coil, the galvanometer deflects to the right by 10 units.



What is the deflection of the galvanometer as the magnet leaves the coil?

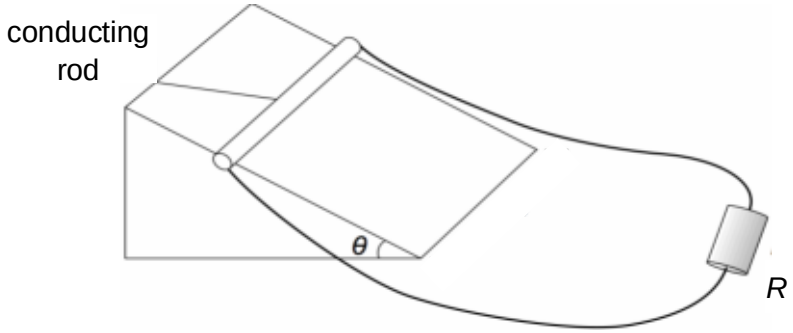
A to the left by less than 10 units

B to the left by more than 10 units

C to the right by less than 10 units

D to the right by more than 10 units

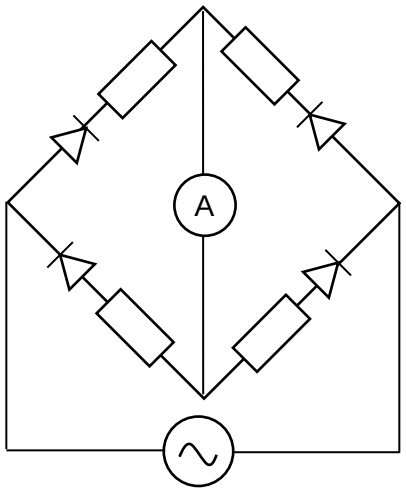
32 A metal rod, length *L* and mass *m*, is placed on smooth plane, which makes an angle q to the horizontal. The rod is connected to a resistor of resistance *R* using light and flexible wires. The rod is released from rest at the top of the plane and moves in a uniform magnetic flux density *B* that is vertically downwards.



What is the rate of loss of gravitational potential energy when the rod reaches terminal velocity?

A $\dfrac{m^2g^2R\sin\theta}{B^2L^2\cos\theta}$ **B** $\dfrac{m^2g^2R\sin^2\theta}{B^2L^2\cos^2\theta}$ **C** $\dfrac{m^2g^2R\sin^2\theta}{B^2L^2\cos\theta}$ **D** $\dfrac{m^2g^2R\sin\theta}{B^2L^2\cos^2\theta}$

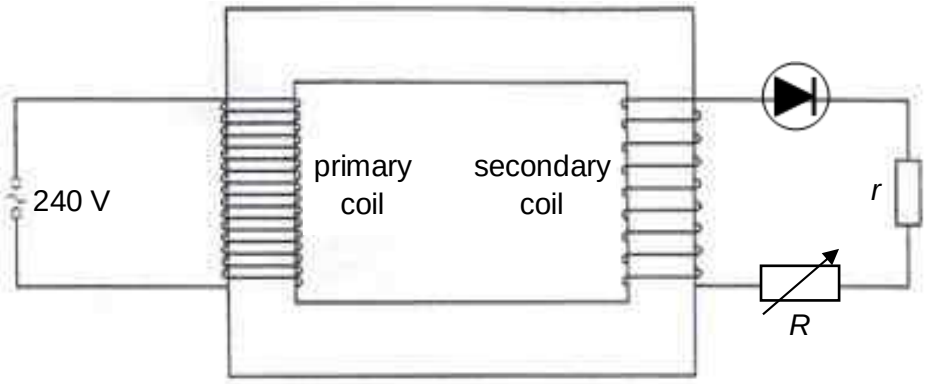
33 Four identical resistors are arranged as shown. Given that the peak current registered by ammeter A is I.



What is the mean current through A?

A 0 **B** $0.5I$ **C** $0.64I$ **D** $0.71I$

34 The diagram shows an iron-cored ideal transformer. The primary coil of the transformer has 200 turns and is connected to a 240 V r.m.s. supply. The secondary coil has 10 turns and is connected, through an ideal diode, to a resistive load, *r* with resistance 2.0 Ω and a variable resistor with resistance *R*.

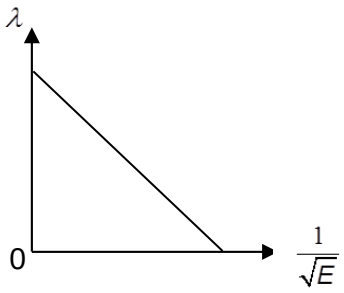


Given that the power dissipated in *r* doubles to *P* when *R* is halved. What is the value of *P*?

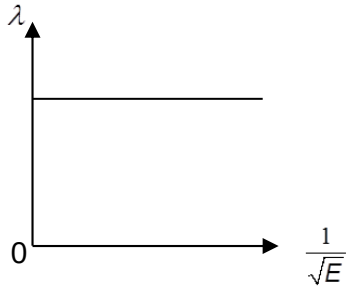
A 3.09 W **B** 6.18 W **C** 12.4 W **D** 24.7 W

35 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?

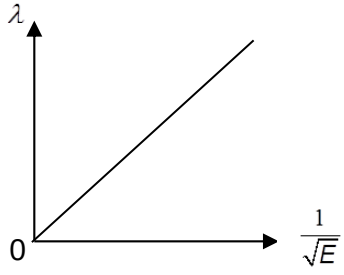
A



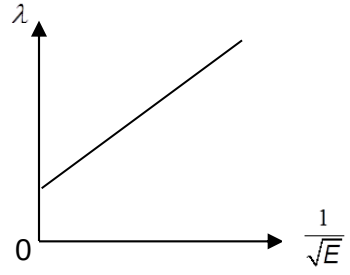
B



C



D



36 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 dark lines on a coloured background **B** dark lines on a white background

C coloured lines on a black background **D** coloured lines on a white background

37 Which of the following are necessary conditions to achieve population inversion in the lasing agent?

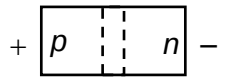
A light amplification and pumping

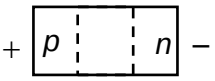
B pumping and metastable state

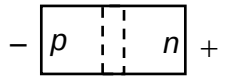
C metastable state and stimulated emission

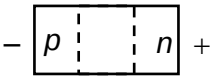
D stimulated emission and light amplification

38 The following diagrams show a semiconductor *p*-*n* junction with a potential difference applied across it. Which diagram shows a forward-bias state?

A 

B 

C 

D 

39 Which of the following is not conserved in a nuclear process?

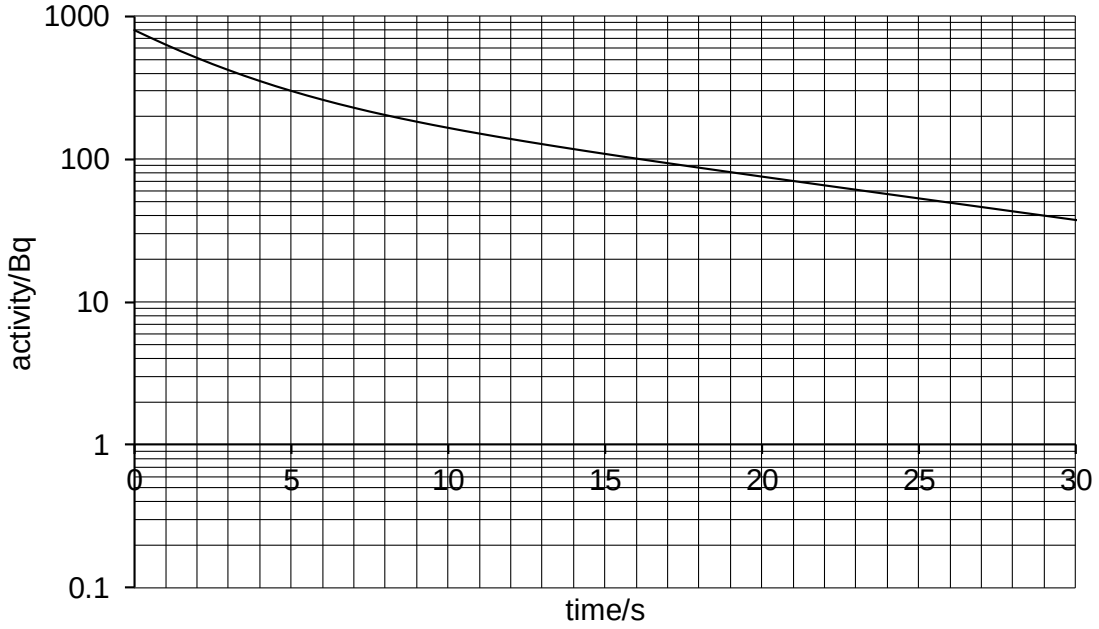
A charge

B momentum

C total number of neutrons

D total number of nucleons

40 The composite decay curve of two independent radioactive compounds which decay by emitting the same particle resulting in stable daughter nuclei are shown below.



What is the smaller half-life of the two compounds?

A 1 s **B** 2 s **C** 9 s **D** 10 s

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS

9646/02

Paper 2 Structured Questions

19 September 2016

1 hour 45 minutes

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 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.

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	/72

This document consists of **21** 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	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant.	λ	=	$\frac{0.693}{t_{1/2}}$

For Examiner's Use

1 An object of mass 1.5 kg is released from a stationary hot air balloon. Fig. 1.1 shows how the velocity of the object varies with time.

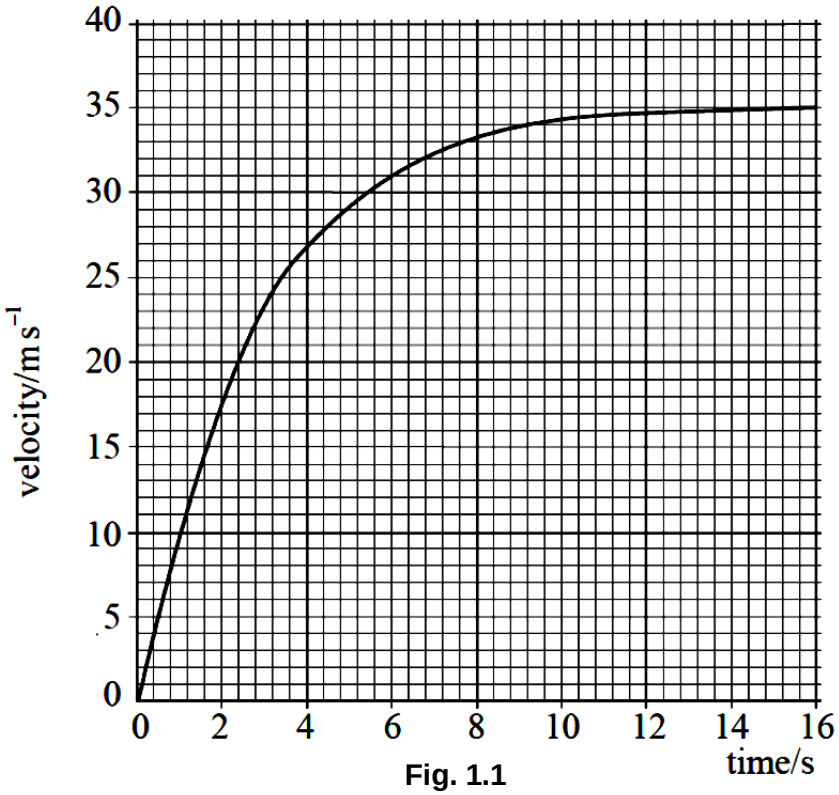


Fig. 1.1

(a) Describe how the acceleration of the falling object changes over the first 16 s.

.....

.....

..... [2]

(b) Explain how the forces acting on the falling object cause the changes in acceleration described in **part (a)**.

.....

.....

..... [2]

(c) Use Fig. 1.1 to determine the acceleration of the object 5.0 s after it was released.

acceleration = ... m s^{-2} [2]

For Examiner's Use

(d) Show that the distance fallen in the first 16 s is approximately 430 m.

[1]

2 Fig. 2.1 shows a spinning swing ride at an amusement park which has two angular speed settings. The lower speed setting causes the carriage to swing at an angle $\theta = 5.0°$, and the higher speed setting causes it to swing at an angle $\theta = 8.0°$. The average mass of each carriage with its rider is 50.0 kg.

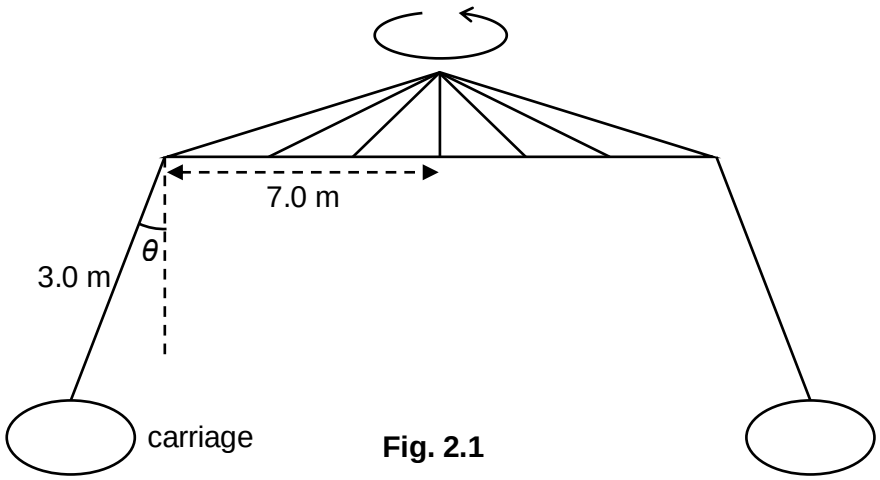


Fig. 2.1

(a) (i) By considering the forces acting on the carriage, show that the angular velocity ω is given by the equation

$$\omega = \sqrt{\frac{g \tan\theta}{(7.0 + 3.0\sin\theta)}}$$

where g is acceleration due to gravity, 9.81 m s^{-2}.

[2]

For Examiner's Use

(ii) Hence, calculate the linear speed for each speed setting.

Low speed setting = ... m s^{-1}

High speed setting = ... m s^{-1} [2]

(b) The ride, with 16 carriages attached, starts out at the low speed setting before it gradually speeds up to the high speed setting. This requires additional energy from the central motor.

(i) Determine the average kinetic energy of each carriage with its rider at the low speed setting.

average kinetic energy = ... J [1]

(ii) Determine the gain in gravitational potential energy of each carriage with its rider when the ride goes from the low to the high speed setting.

gain in gravitational potential energy = ... J [1]

For Examiner's Use

(iii) Hence, determine the additional energy required for the ride to go from the low to the high speed setting when it is operating at full capacity.

additional energy = ... J [3]

For Examiner's Use

3 **(a)** Define angular velocity for an object travelling in a circle.

.....

..... [1]

(b) Show, for a circular orbit of a small satellite around a larger mass, that ω, the angular velocity of rotation is related to r, the radius of the orbit by the relationship $\omega^2 \propto r^{-3}$.

[1]

(c) The Lagrangian point is an orbital position where a small object can maintain a stable position relative to two larger bodies. One such point is the Sun-Earth Lagrangian point, L_1, where the satellite Deep Space Climate Observatory (DSCOVR) was launched into. The relative positions of the Sun, Earth and L_1 are shown in Fig. 3.1. At L_1, DSCOVR is able to orbit the Sun with the same angular velocity as Earth, maintaining its position along the Sun-Earth axis throughout its orbit around the Sun.

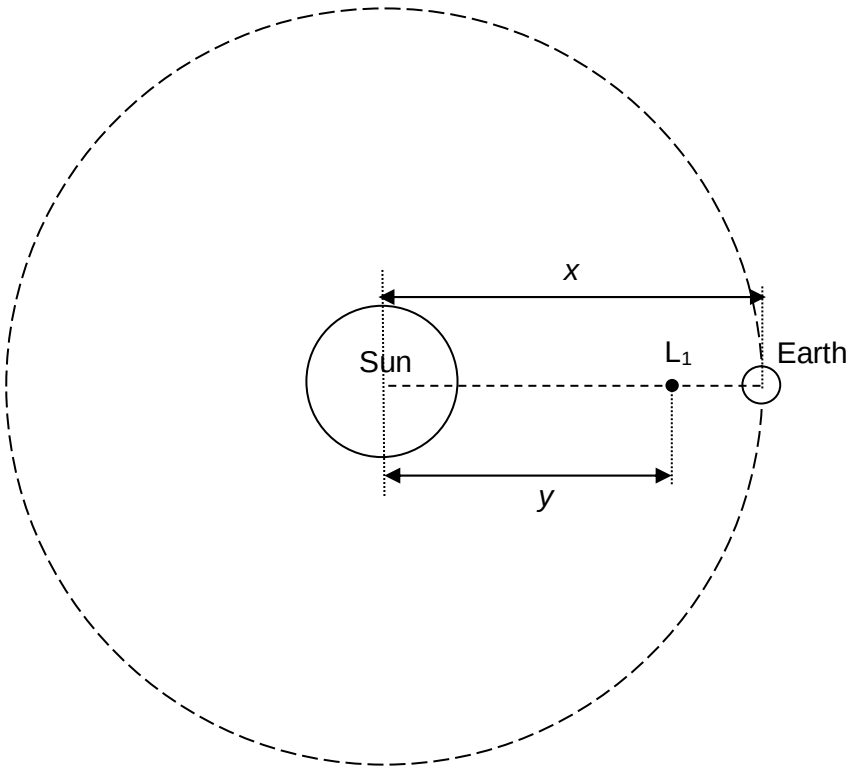


Fig. 3.1

For Examiner's Use

(i) The radius of orbit of DSCOVR at L_1, represented by the distance y, is less than the radius of orbit of Earth, x. Explain why the relationship in **(b)** does not apply to the satellite.

.....

.....

.....

..... [2]

(ii) Hence, or otherwise, show that the relationship of x and y can be represented by the equation

$$\frac{M_S}{y^2} - \frac{M_E}{(x-y)^2} = 5.95 \times 10^{-4}(y)$$

where M_S is the mass of Sun and M_E is the mass of Earth. Explain your working.

[2]

(iii) The satellite DSCOVR gathers information about the Sun and sends them to a station on Earth. State one advantage and one disadvantage of maintaining the DSCVOR at an orbit at L_1.

Advantage: .....

.....

.....

Disadvantage: .....

.....

..... [2]

For Examiner's Use

4 Fig. 4.1 shows an arrangement for analyzing the light emitted by a point source.

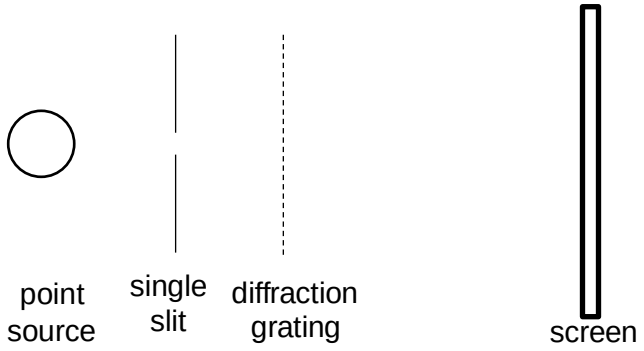


Fig. 4.1

(a) Suggest a light source that would emit a continuous spectrum.

.....[1]

(b) The light source emits a range of wavelengths from 500 nm to 700 nm. The light is incident on a diffraction grating that has 10 000 lines per centimetre.

(i) Calculate the angle from the straight-through direction at which the first order maximum for the 500 nm wavelength is formed.

angle = ... ° [2]

(ii) Calculate the angular separation of the first order spectrum.

angular separation = ... ° [2]

(iii) The screen is positioned 2.0 m from the grating. Calculate the width of the first order spectrum on the screen.

width = ... m [2]

(iv) Describe the pattern which would be observed.

.....

..... [1]

For Examiner's Use

5 Fig. 5.1 shows a simple electric motor made up of an armature placed between two permanent magnets. The armature consists of a single square coil of copper wire of resistance 0.50 Ω.

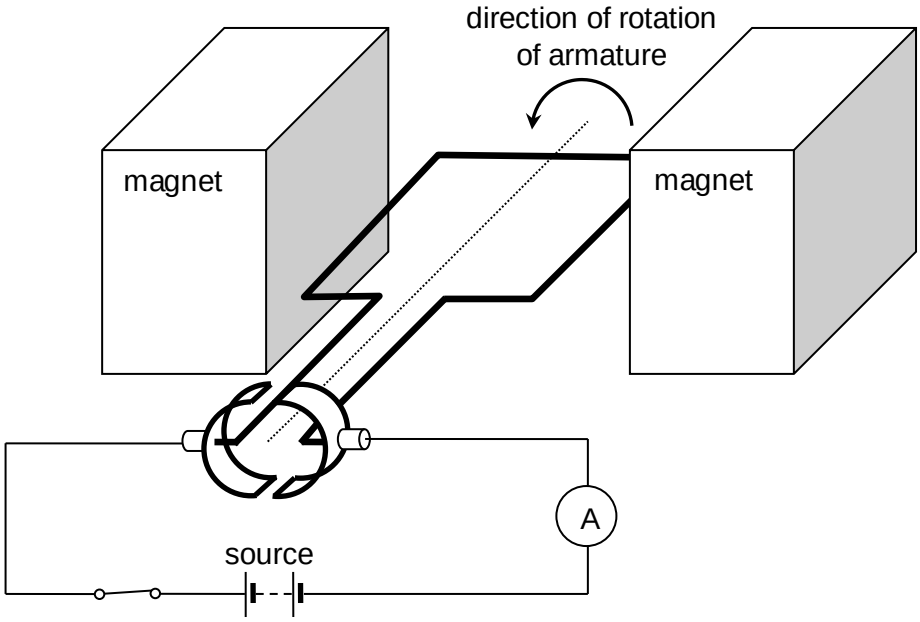


Fig. 5.1

The armature carries a current of 0.55 A just before it starts to move from the position as shown in Fig. 5.1.

(a) The current through the armature falls to below 0.55 A once the motor starts rotating. Explain why this is so.

.....

.....

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.....

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..... [4]

For Examiner's Use

(b) When the armature is rotating at a constant rate, the minimum current in the armature decreases to 0.14 A. Calculate the maximum rate at which the magnetic flux linkage through the armature changes.

maximum rate = ... Wb s^{-1} [3]

6 **(a)** One property of a laser is that it can direct a large amount of energy onto a very small spot. In one particular application, the laser emits a 3.0 mJ pulse in 1.0 ns, focused on a spot 8.0×10^{-10} m^2 in area. Calculate the power per unit area at the target.

power per unit area = ... W m^{-2} [2]

(b) Using the ideas of population inversion and stimulated emission, explain how a laser could deliver an intense and directed light beam.

.....

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.....

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.....

..... [4]

For Examiner's Use

7 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.

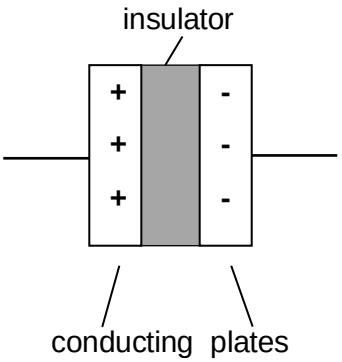


Fig. 7.1

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) The capacitor is now charged. Fig. 7.2 shows the values of potential difference V and the corresponding amount of charge Q.

***V*/ V**	***Q*/ μC**
0.4	1.9
1.3	6.1
2.5	14.3
3.3	15.5
4.2	19.7
5.1	23.5

Fig. 7.2

(i) On Fig. 7.3, sketch a line to show the variation of the amount of charge Q with the potential difference V between the plates. [1]

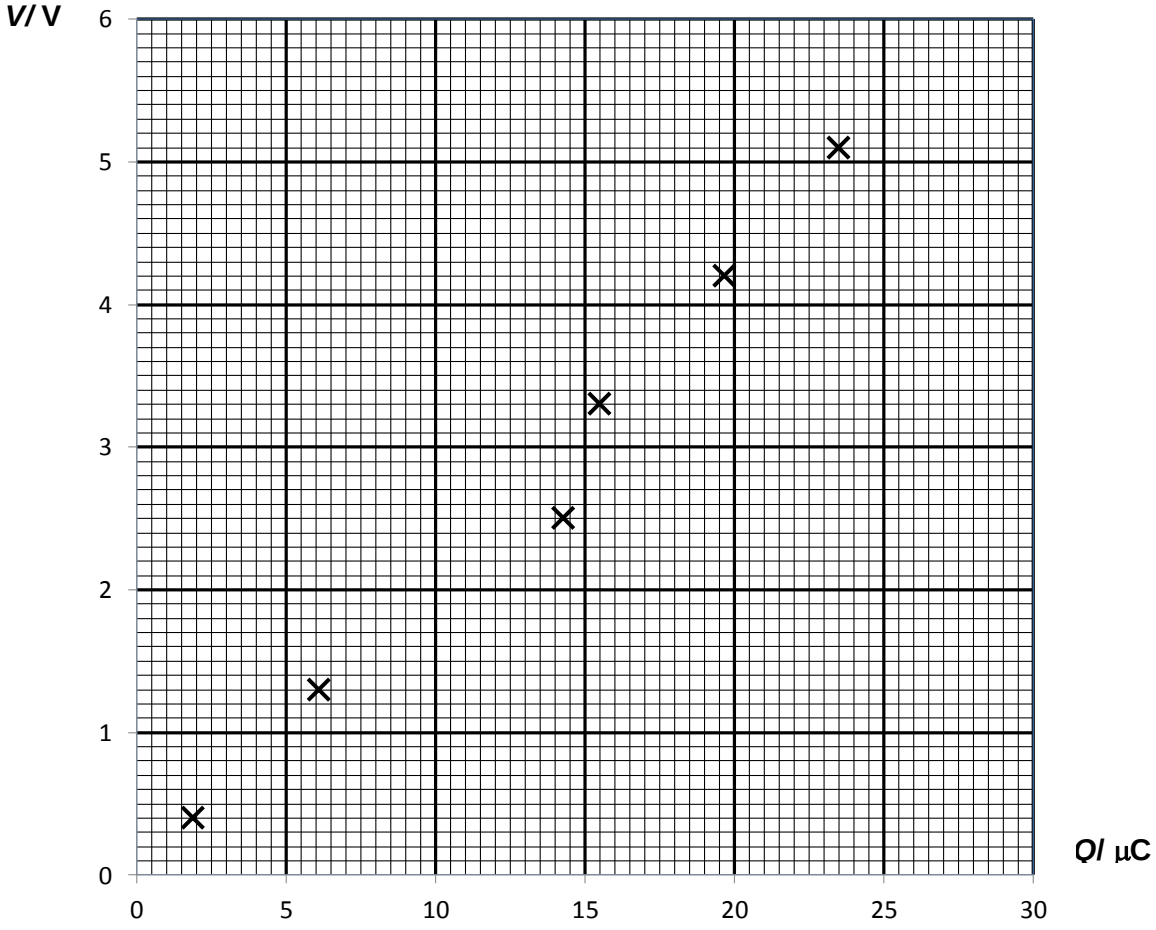


Fig. 7.3

(ii) State the quantity represented by the

1. gradient of the line,

..... [1]

2. area under the line.

..... [1]

(iii) Hence show that the energy E stored in a capacitor is $\frac{1}{2} CV^2$.

[1]

For Examiner's Use

(b) The capacitor is now discharged by connecting it across a resistor of resistance *R*. Fig. 7.4 shows the variation with time *t* of the potential difference *V* across the resistor.

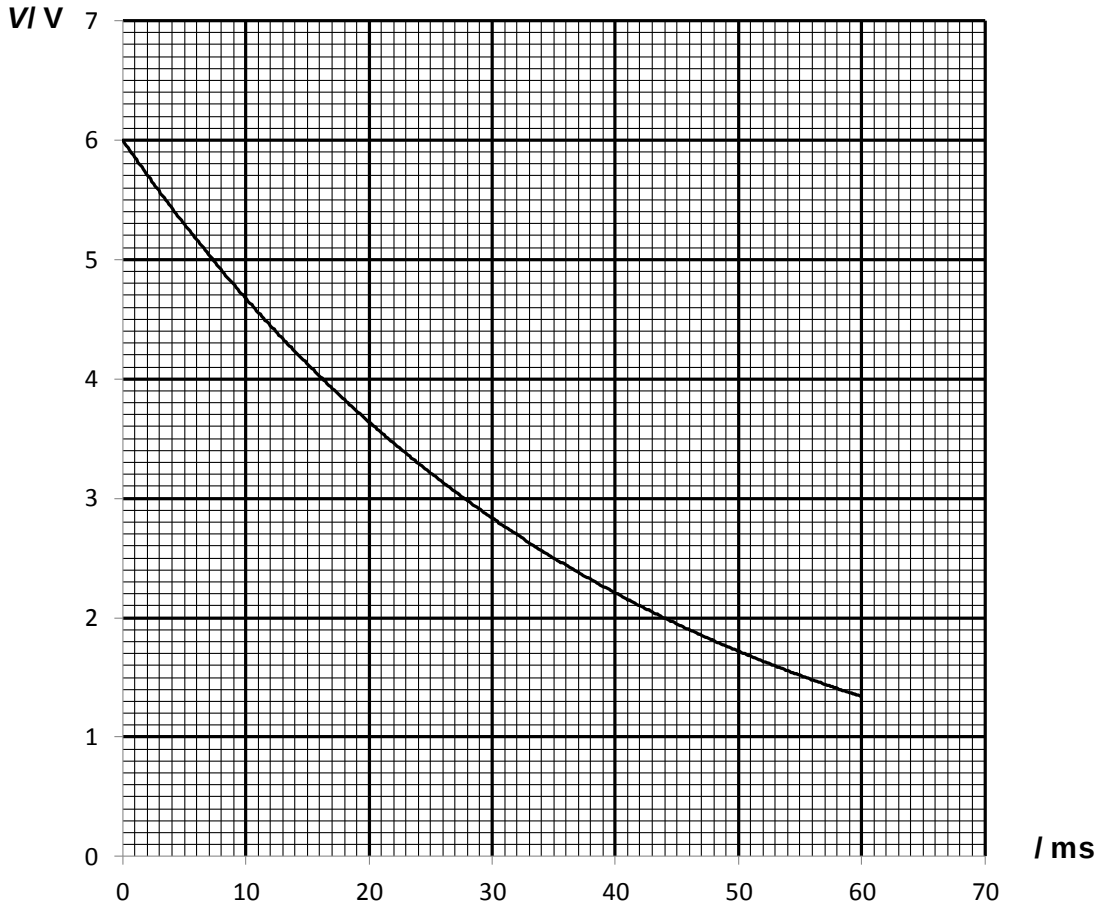


Fig. 7.4

(i) **1.** Using Fig. 7.3 and Fig. 7.4, determine the initial amount of charge stored.

charge = ... C [2]

2. Calculate the capacitance *C*.

capacitance = ... $C\ V^{-1}$ [1]

(iii) Calculate the energy lost when the capacitor has been discharged for 45 ms.

energy lost = ... J [3]

(b) When discharging through the resistor of resistance R, the variation of the potential difference V with time t is given by the following equation:

$$V = V_o e^{-t/RC}$$

(i) Deduce the base units of C.

base units = ... [2]

(ii) State how the value of RC affects the rate of discharge.

.....

..... [1]

For Examiner's Use

(d) Fig 7.5 shows an A.C. supply connected to resistor-capacitor (RC) circuit containing an ideal diode. Fig 7.6 shows the potential difference measured by the CRO.

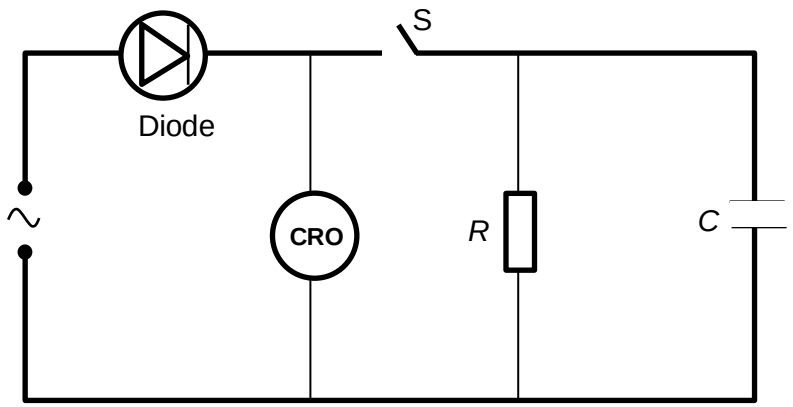


Fig. 7.5

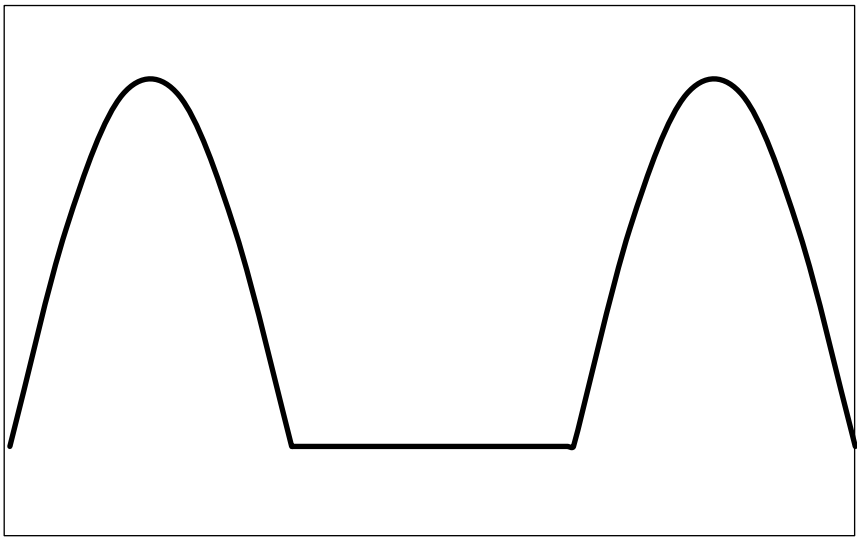


Fig. 7.6

Switch S is now closed.

(i) Sketch on Fig. 7.6, the expected display on the CRO. [1]

(ii) State one possible application of the RC circuit.

.....

..... [1]

8 Gamma radiation is often used to kill living micro-organisms, in a process called irradiation. Applications of this include sterilizing medical equipment, removing decay-causing bacteria from food or preventing fruits and vegetables from sprouting to maintain freshness and flavour.

Despite their cancer-causing properties, gamma rays are also used to treat some types of cancer since the rays kill cancer cells too. In a procedure called gamma knife surgery, multiple concentrated beams of gamma rays are directed on the growth in order to kill the cancerous cells.

A student wishes to investigate how different thicknesses of lead absorbers affect the count rate from a radioactive gamma source in his school science laboratory. He was told by his Physics teacher that the count rate C obeys the equation:

$$C = C_0 e^{-\mu x}$$

where x is the thickness of the lead absorbers, and C_o is a constant.

Design a laboratory experiment to verify this equation and determine the value of the constant μ.

You may assume that the following equipment is available, together with any other apparatus that may be found in a school or college science laboratory:

Ammeter	Voltmeter
Connecting wires	Variable d.c. power supply
Lead plates of different thicknesses	Geiger-Müller tube
Oscilloscope	Datalogger
Ratemeter	Signal generator
Source handling tool	Metre rule

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

(a) the equipment you would use for the investigation,

(b) the procedure to be followed, including how the count rate would be measured,

(c) the control of variables,

(d) any safety precautions you would take.

(e) any precautions that you would take to improve the accuracy of the experiment.

Diagram

.....

.....

.....

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS

9646/03

Paper 3 Longer Structured Questions

26 September 2016

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 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 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	
Section A	
1	
2	
3	
4	
5	
Section B	
6	
7	
8	
Total	

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	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant.	λ	=	$\frac{0.693}{t_{1/2}}$

For Examiner's Use

Section A

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

1 A rear-view mirror is mounted on the side of a lorry cab. The mirror and its support can be modelled as a mass-spring system with the mass m of the mirror attached to a spring of force constant k.

When the mirror is displaced from its equilibrium position, it oscillates in simple harmonic motion with a natural frequency f given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

A mirror of $m = 2.20$ kg and support of $k = 2.4 \times 10^3$ N m^{-1} undergoes oscillations of amplitude 12.0 mm.

(a) Calculate

(i) the maximum acceleration of the mirror.

maximum acceleration = ... m s^{-2} [2]

(ii) the velocity of the mirror at a position 4.0 mm above its lowest position.

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

For Examiner's Use

(b) When the lorry is travelling at low engine speeds, the driver finds that the amplitude of oscillation of the mirror is too great to allow a clear view behind. However, at higher engine speeds, the mirror and its image are steady.

Explain how this difference arises. You should include a sketch graph of how the amplitude of the vibration of the mirror may vary with frequency of the engine to illustrate your answer.

.....

.....

.....

.....

.....

..... [4]

2 **(a)** Explain what is meant by centre of gravity of a body.

.....

.....

..... [1]

(b) A toy of uniform mass 200 g and width 20 cm is placed on smooth ground. The centre line through the toy is *C*. A light piece of plasticine of mass 10 g is placed on the left edge such that it is displaced by an angle of 10°. The reaction force from the ground is *R*.

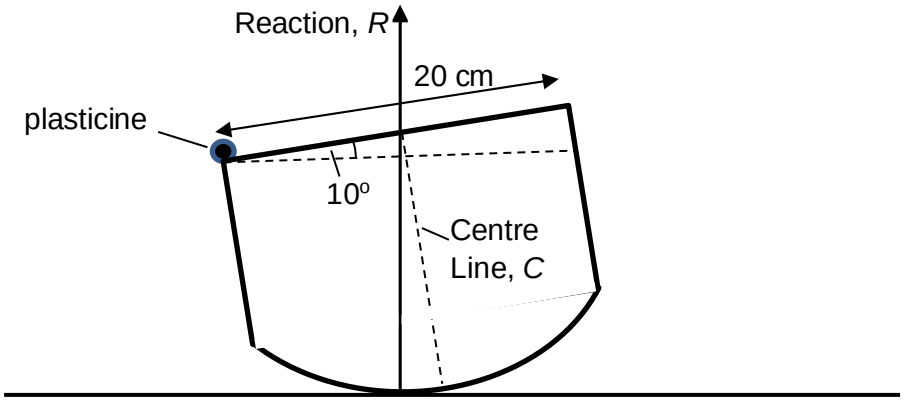


Fig 2.1

(i) On Fig. 2.1, mark the position of the centre of gravity of the toy before the plasticine is placed. Label the point as O. [1]

For Examiner's Use

(ii) Calculate the value of *R*.

R = ... N [1]

(iii) Calculate the horizontal distance between O and *R*.

distance = ... m [3]

(iv) Explain why the line of action of *R* needs to be nearer to O than to the plasticine.

.....

.....

..... [1]

3 **(a)** State the *first law of thermodynamics*.

.....

.....

..... [1]

(b) Fig. 3.1 shows a fixed mass of ideal gas in a cylinder. Starting at an initial thermodynamic state A, it is compressed by two different processes independently.

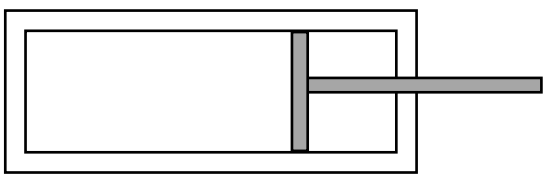
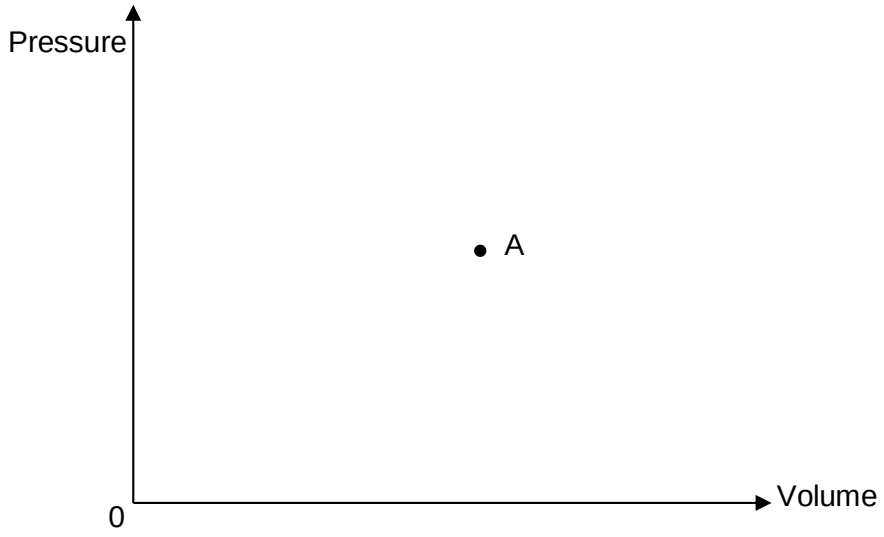


Fig 3.1

The same amount of work is done to compress the gas in process AB at constant temperature and process AC with the gas thermally insulated.

For Examiner's Use

(i) On Fig. 3.2, sketch two labelled lines to show processes AB and AC respectively.



[2]

Fig 3.2

(ii) Using your answer in **(a)**, compare and explain the steepness of the lines for processes AB and AC.

.....

.....

..... [2]

(c) State the required properties of the cylinder wall for the following processes:

(i) AB

.....

..... [1]

(ii) AC

.....

..... [1]

(d) Using first law of thermodynamics, explain why process AB requires longer time duration for the compression stroke.

.....

..... [1]

For Examiner's Use

4 A researcher has a few small identical blocks of metal X, as shown in Fig. 4.1. Each block is to be melted under high temperature and reshaped into resistive conductors of length L as shown in Fig. 4.2.

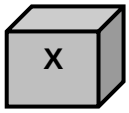


Fig. 4.1

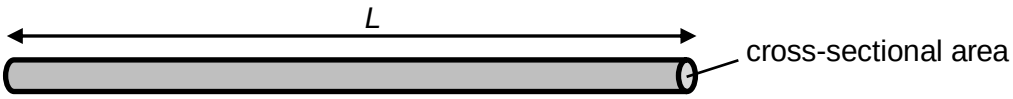


Fig. 4.2

(a) Given that the volume of each block is V and the resistivity of metal X is ρ, show that the resistance R measured across its cross-sectional area, is directly proportional to the square of the length of the conductor, L^2.

[1]

(b) Conductor P and Q are two such conductors melted from metal X, with different L and cross-sectional area. Conductor P has a length of 1.2 m and a resistance of 5.0 Ω. Determine the resistance of conductor Q, given that its length is 1.0 m.

resistance = ... Ω [2]

For Examiner's Use

(c)

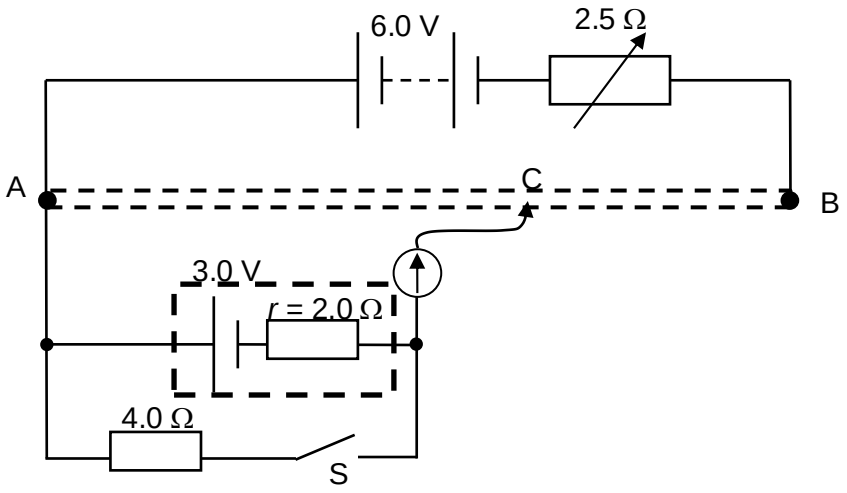


Fig. 4.3

A potentiometer circuit with a missing resistive conductor is shown in Fig. 4.3. Switch S is open initially.

(i) Conductor P is placed across points A and B. Determine the balance length.

balance length = ... m [2]

(ii) Taking into consideration the percentage uncertainty in the measurement of balance length, state and explain whether conductor P or Q is more preferable to be placed across points A and B, in order to measure the potential difference across a 3.0 V test cell.

.....

.....

..... [2]

(iii) Switch S is then closed. Explain, without further calculation, whether the balance length will increase or decrease.

.....

.....

..... [2]

For Examiner's Use

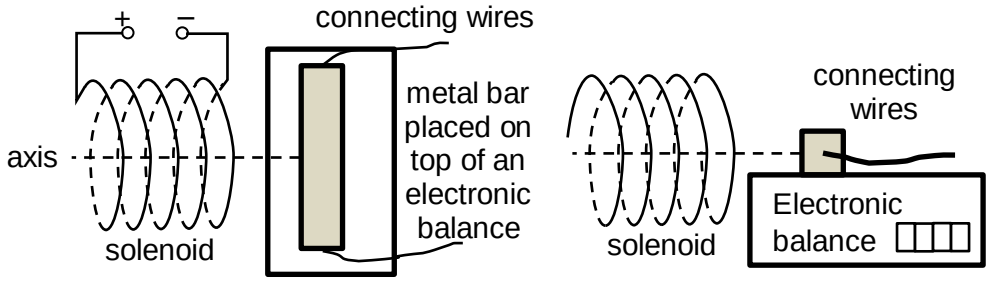
5 **(a)** Define magnetic flux density.

.....

.....

..... [1]

(b) Fig. 5.1 below shows a solenoid, with a tiny metal bar of length 0.020 m placed across its axis. The metal bar is resting on an electronic balance.



(a) Top view **(b)** Side view

Fig. 5.1

When a current is passed through the metal bar, the reading on the electronic balance decreases. The current through the solenoid is slowly increased until the reading on the electronic balance just reaches zero.

(i) On Fig. 5.1a, draw an arrow to indicate the direction of current through the metal bar, and label it *C*. Explain your answer.

.....

.....

..... [3]

(ii) Given that metal bar has a mass of 0.100 kg and the current passing through the metal bar is 5.0 A, calculate the magnetic flux density due to the solenoid.

magnetic flux density = ... T [2]

(c) For each of the following changes made to the setup, state and explain whether the metal bar needs to be brought closer to or further away from the solenoid to maintain an electronic balance reading of zero.

(i) The current in solenoid is increased.

.....

..... [1]

(ii) The metal bar is tilted about the solenoid's axis at an angle of 30°.

.....

..... [1]

For Examiner's Use

Section B

Answer **two** questions in this section.

6 **(a)** The decay of a stationary radioactive nuclide radium (Ra) into radon (Rn) may be represented by the equation

$$^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + \alpha$$

The rest masses of the three particles are given in Fig. 6.1 below.

particle	rest mass/u
$^{226}_{88}$Ra	226.025410
$^{222}_{86}$Rn	222.017578
α	4.002603

Fig. 6.1

(i) Calculate the energy released for this process.

energy released = ... MeV [2]

(ii) Determine the ratio of the kinetic energy of the alpha particle to Radon (Rn) after the decay.

ratio = ... [2]

(iii) Hence calculate the kinetic energy of the alpha particle after the decay.

kinetic energy = ... MeV [2]

(iv) Comment on the kinetic energy distributions of the particles after the decay, by considering the property of the particles.

.....

..... [1]

For Examiner's Use

(b) Three naturally occurring isotopes of carbon on earth are the stable carbon-12 (^{12}C), carbon-13 (^{13}C) and the radioactive carbon-14 (^{14}C). These isotopes are present in the following amounts as shown in Fig. 6.2.

isotope	percentage/%
^{12}C	98.89
^{13}C	1.11
^{14}C	0.00000000013

Fig. 6.2

The radiocarbon method is based on the rate of decay of the radioactive or unstable ^{14}C, which is formed in the upper atmosphere through the effect of cosmic ray neutrons upon nitrogen-14 (^{14}N). The reaction is represented by the equation below

$$^{14}_{7}N + n \rightarrow {}^{14}_{6}C + p$$

During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of ^{14}C as the atmosphere. When it dies, it ceases to acquire ^{14}C but the ^{14}C within its biological material at that time will continue to decay, and so the ratio of ^{14}C to ^{12}C in its remains will gradually decrease.

^{14}C undergoes radioactive beta decay to produce ^{14}N, beta particle and a neutrino particle as given by the following equation:

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

To determine the half-life of ^{14}C, Willard Frank Libby conducted tests against sequoia trees with known dates from their tree rings. He measured the activities of several sequoias and recorded the data in Fig. 6.3.

t/years	*A*/Bq	ln (*A*/Bq)
0	20000	
500	18826	
1000	17721	9.783
1500	16681	
2000	15702	9.662
2500	14781	9.601
3000	13913	

Fig. 6.3

(i) Complete Fig. 6.3. [2]

For Examiner's Use

(ii) Sketch the variation with time of the natural logarithm of activity of ^{14}C in Fig. 6.4 and draw the best fit line. [3]

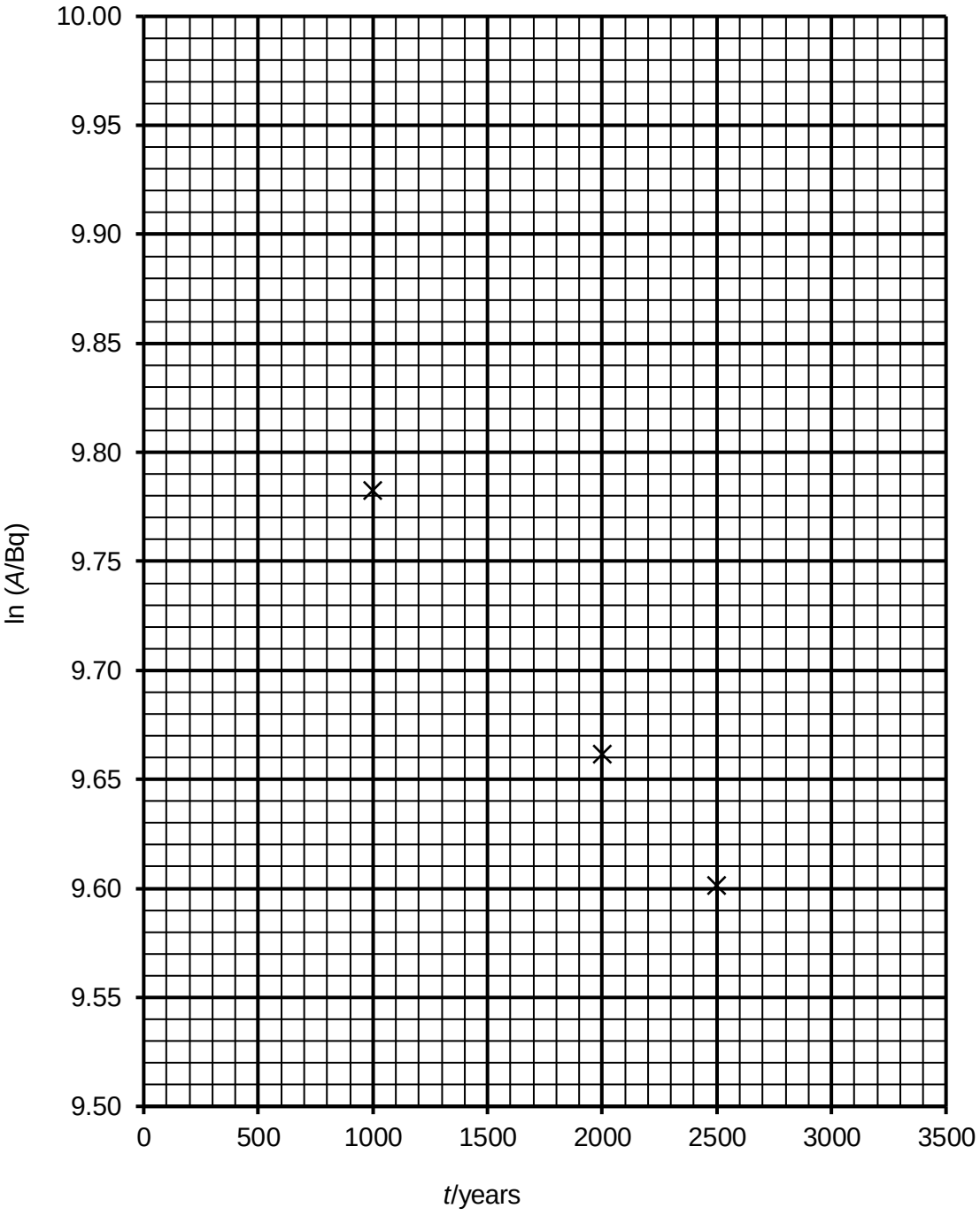


Fig. 6.4

(iii) Using Fig. 6.4 determine the half-life of ^{14}C.

half-life = ... years [2]

For Examiner's Use

As ^{14}C decays at a known rate, the proportion of radiocarbon can be used to determine the age of a material.

A piece of wood containing 28.0 g of ^{12}C is found by archaeologists in an archaeological site. The rate of decay of ^{14}C of the wood is 240 min^{-1}.

(iv) Determine the number of ^{14}C atoms in the wood.

number = ... [2]

(v) Using Fig. 6.2 and the answer to **(b)(iii)**, estimate the age of the wood.

age = ... years [4]

For Examiner's Use

7 **(a)** A positively charged particle is accelerated by a uniform electric field**.**

(i) Explain what is meant by a uniform electric field.

.....

.....

..... [2]

(ii) Describe the motion of the positively charged particle if it is initially projected

1. in the direction of the electric field.

.....

..... [1]

2. in the direction perpendicular to the electric field.

.....

..... [1]

(b) In an electron microscope, an electron lens has two cylinders which are at potentials of +500 V and -100 V respectively. An electron beam passes at high speed into the lens from the top. A cross-section of the two cylinders is shown *in full scale* in Fig. 7.1. The dotted lines are equipotential lines.

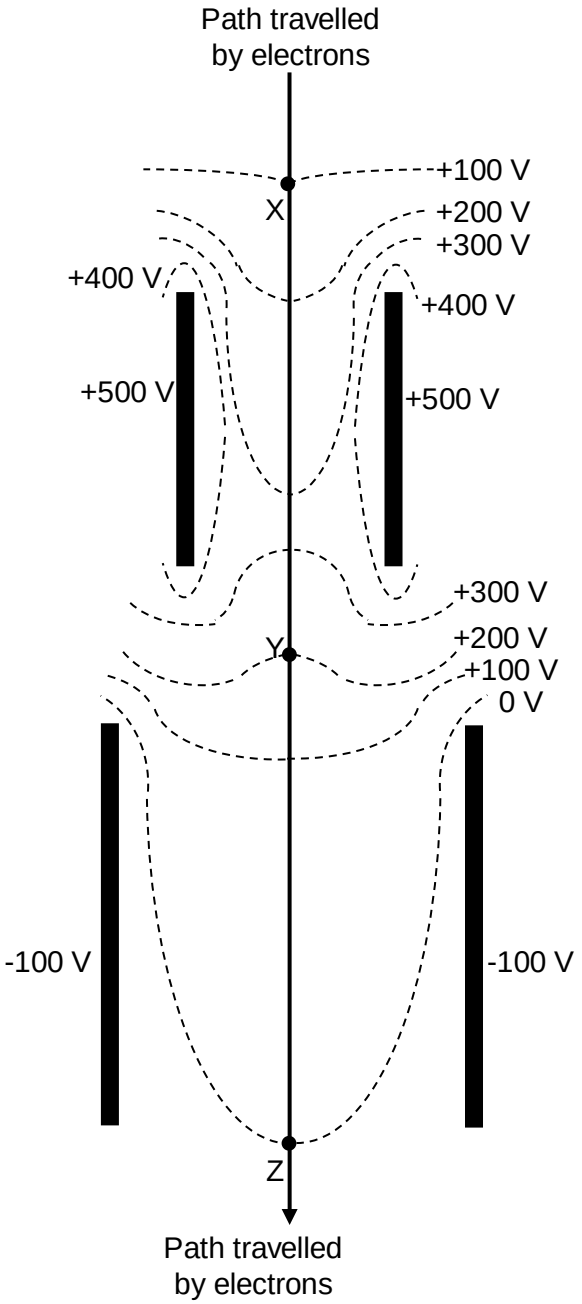


Fig. 7.1

(i) **1.** Estimate the electric field strength at Y.

electric field strength = ... V m^{-1} [2]

2. On Fig. 7.1, indicate the direction of the electric field strength at Y. [1]

3. Hence, determine the magnitude and direction of the electric force acting on an electron when it is at Y.

magnitude of force = ... N [1]

direction = ... [1]

(ii) Determine the change in kinetic energy of an electron moving in a vacuum from X to Z.

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

For Examiner's Use

(c) In an isolated system, four identical charges each carrying charge *-q*, are arranged symmetrically about an insulating circular ring of radius *R* as shown in Fig. 7.2. Points X and X' lies along the central axis of the ring. Point X is at a distance *h* from the centre O of the ring.

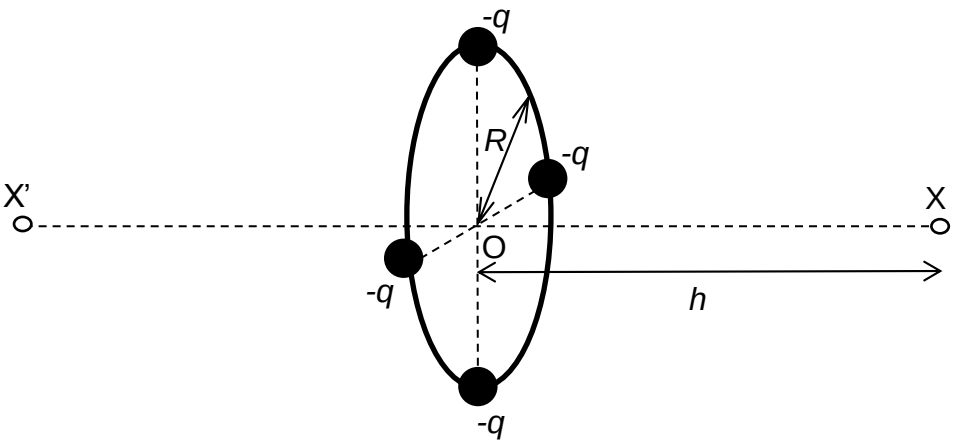


Fig. 7.2

(i) State the magnitude of the electric field strength at O.

electric field strength = ... [1]

(ii) Derive an expression in terms of *q*, *h*, *R* and the permittivity of free space ε_0 as necessary for

1. the distance between one of the charges and point X.

[1]

2. the electric potential at point X.

[2]

For Examiner's Use

3. the magnitude of the electric field strength at X.

[2]

(iii) On Fig. 7.2, indicate the directions of the electric force acting on a positive charge when it is placed at X and X' respectively. [1]

(iv) Hence, state and explain whether the subsequent motion of a stationary positive charge that is initially released from rest at X will be simple harmonic.

.....

.....

..... [2]

For Examiner's Use

8 **(a)** State what is meant by the term *photoelectric effect*.

.....

..... [2]

(b) Describe **two** experimental observations associated with the photoelectric effect and explain how each deviates from predictions of the classical wave theory.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

(c) Suggest a possible value for the photon energy of visible light. Show your working.

photon energy = ... J [2]

For Examiner's Use

(d) In a photoelectric experiment, an ultraviolet (UV) source of frequency *f* is used instead of a visible light source. Two metal plates X and Y are contained in an evacuated glass container and are connected to a circuit as shown in Fig. 8.1. The monochromatic UV point source is supplied with a power *P* and placed at a distance *d* away from the perpendicular axis between the two metal plates.

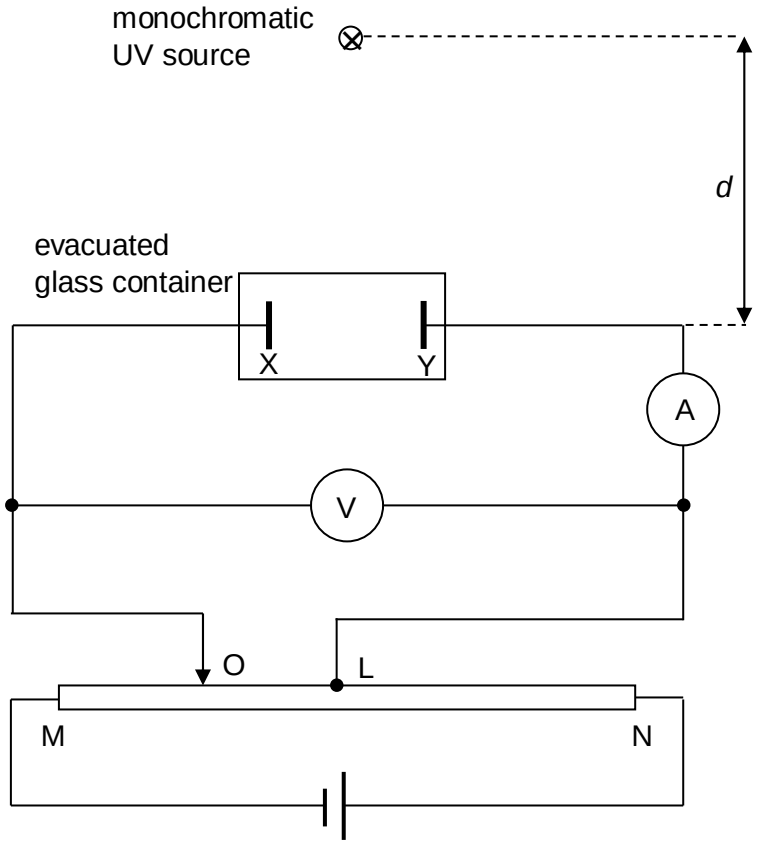


Fig. 8.1

The graph labelled E shown in Fig. 8.2 depicts the relationship between the voltmeter reading and the ammeter reading when metal plate X is the photoelectric emitter.

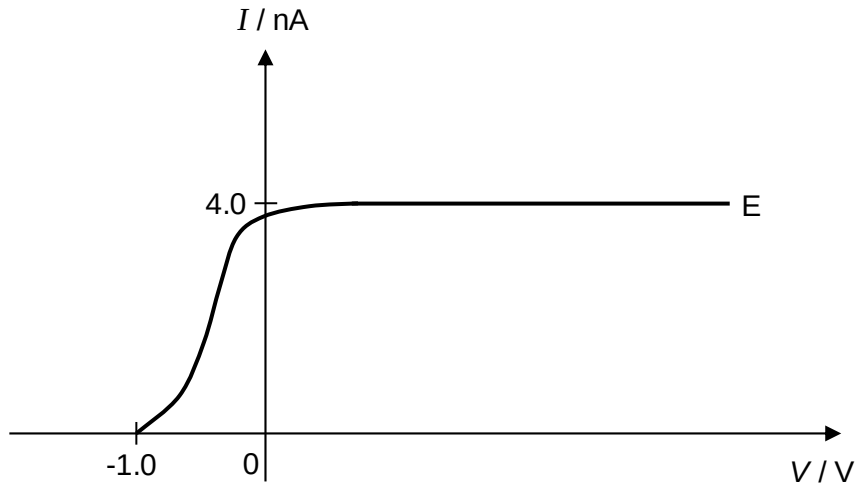


Fig. 8.2

(i) In order to obtain Graph E, the sliding contact O would have to be shifted. Discuss how graph E can be obtained by changing the position of O.

.....

.....

.....

..... [3]

(ii) Metal plate X is made of zinc with a work function of 3.8 eV. Using information from Graph E, determine the wavelength of the monochromatic UV source.

wavelength = ... m [3]

(iii) Sketch, without further calculations, on Fig. 8.2, the respective graphs when the experiment was repeated by making the following two changes independently:

1. The monochromatic UV point source is moved to a distance 2*d* away from the axis along the metal plates. Label the new graph D. [2]

2. The monochromatic UV point source is changed to one with a frequency of 0.8 *f* while supplied with the same power *P*. Label the new graph F. [2]

For Examiner's Use

(iv) To perform another study, metal plate Y which was made of gold was replaced with metal plate Z, made of lead. A new graph G shown in Fig. 8.3 was obtained when the experiment was conducted with plate Z.

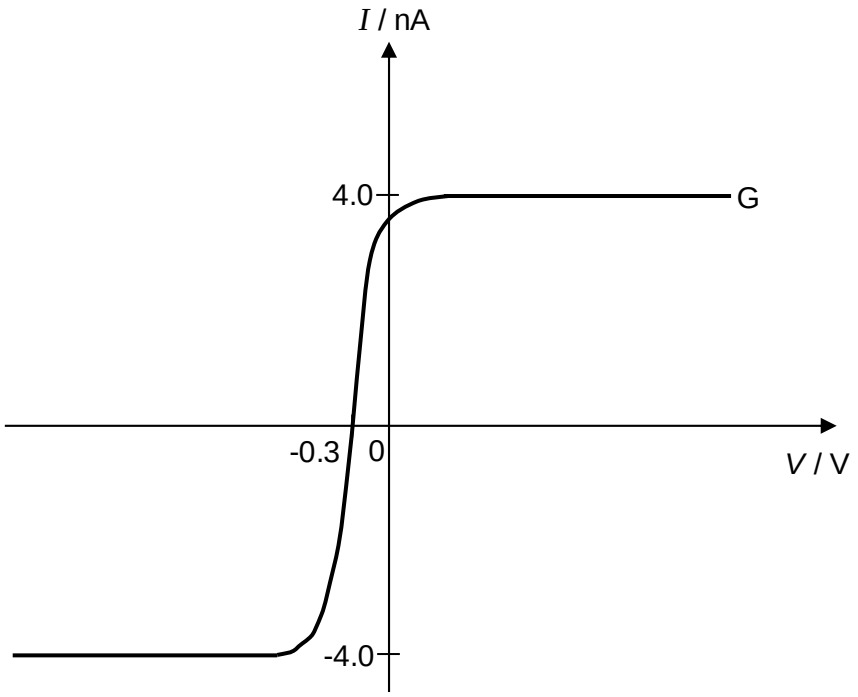


Fig. 8.3

1. By comparing Graph G from Fig. 8.3 to Graph E from Fig. 8.2, suggest a possible reason for the difference in Graph G.

.....

..... [1]

2. From the two graphs in Fig. 8.2 and Fig. 8.3, deduce and list the metal plate X, Y and Z in increasing order of work function.

smallest work function .....

.....

largest work function .....

[1]

2016 H2 Prelim Paper 1 Answer Key

1	B	11	A	21	D	31	B
2	D	12	C	22	C	32	B
3	D	13	A	23	C	33	C
4	B	14	B	24	D	34	C
5	C	15	C	25	A	35	C
6	D	16	D	26	C	36	A
7	D	17	A	27	C	37	B
8	A	18	A	28	C	38	A
9	C	19	A	29	B	39	C
10	D	20	B	30	A	40	B

H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME: SOLUTION

CLASS: _____ TUTOR'S NAME: _____

PHYSICS 9646/02

Paper 2 Structured Questions

19 September 2016

1 hour 45 minutes

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 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.

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	/72

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	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant.	λ	=	$\frac{0.693}{t_{1/2}}$

For Examiner's Use

1 An object of mass 1.5 kg is released from a stationary hot air balloon. Fig. 1.1 shows how the velocity of the object varies with time.

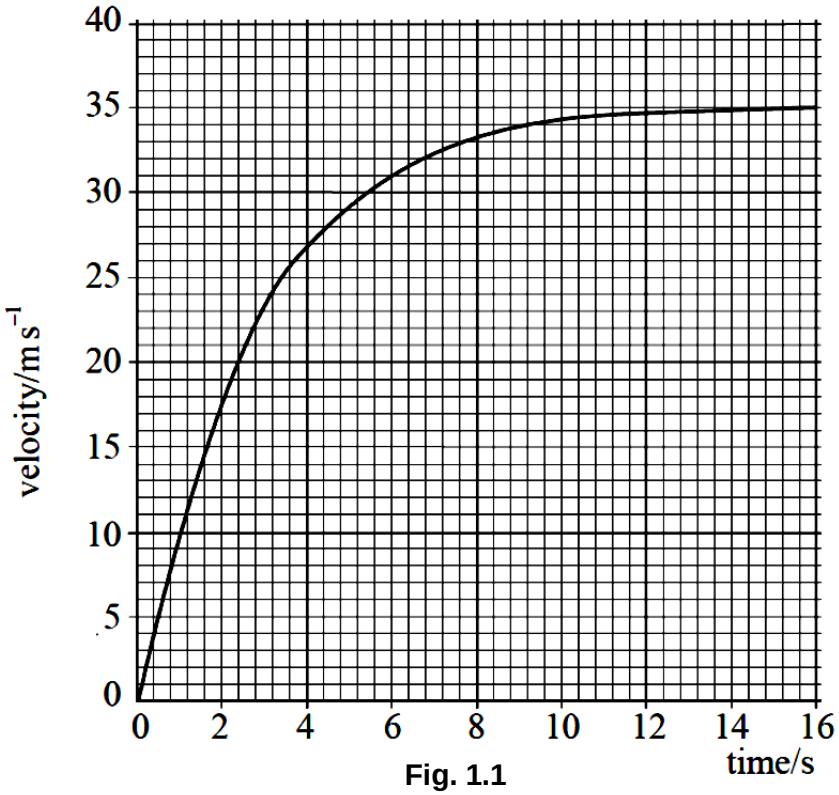


Fig. 1.1

(a) Describe how the acceleration of the falling object changes over the first 16 s.

The gradient of the graph gives acceleration. Acceleration is largest initially [either 1] / it is constant for the first 0.1.2 s [or 1] and decreases to zero (or nearly zero) at 16 s. [1]

.....

.....

..... [2]

(b) Explain how the forces acting on the falling object cause the changes in acceleration described in **part (a)**.

As air resistance increases with speed [1], weight and air resistance acting in opposite direction on the falling object causes resultant force to decrease until zero. [1]

.....

.....

..... [2]

(c) Use Fig. 1.1 to determine the acceleration of the object 5.0 s after it was released.

Tangent drawn at 5.0 s, acceleration = 2.1 m s^{-2} (±0.2)

acceleration = ... m s^{-2} [2]

For Examiner's Use

(d) Show that the distance fallen in the first 16 s is approximately 430 m.
Distance fallen = Area under graph = 460 m (accept 420-480 m)

[1]

2 Fig. 2.1 shows a spinning swing ride at an amusement park which has two angular speed settings. The lower speed setting causes the carriage to swing at an angle $\theta = 5.0°$, and the higher speed setting causes it to swing at an angle $\theta = 8.0°$. The average mass of each carriage with its rider is 50.0 kg.

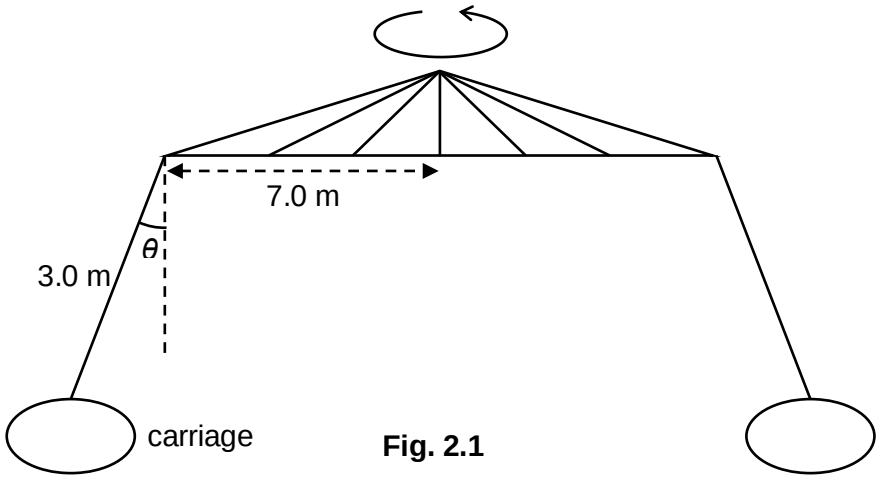


Fig. 2.1

(a) (i) By considering the forces acting on the carriage, show that the angular velocity ω is given by the equation

$$\omega = \sqrt{\frac{g \tan\theta}{(7.0 + 3.0\sin\theta)}}$$

where g is acceleration due to gravity, 9.81 m s^{-2}.

$T\sin\theta = mr\omega^2$ & $T\cos\theta = mg$, hence

$$\tan\theta = \frac{r\omega^2}{g} \quad [1]$$

$$= \frac{(7.0 + 3.0\sin\theta)\omega^2}{g}$$

$$\omega^2 = \frac{g\tan\theta}{(7.0 + 3.0\sin\theta)} \quad [1]$$

[2]

(ii) Hence, calculate the linear speed for each speed setting.

$$v = r\omega = (7.0 + 3.0\sin\theta)\sqrt{\frac{g\tan\theta}{(7.0 + 3.0\sin\theta)}}$$
$$= \sqrt{(9.81)(7.0 + 3.0\sin\theta)\tan\theta}$$
$$v_{low} = 2.50 \text{ m s}^{-1}$$
$$v_{high} = 3.20 \text{ m s}^{-1}$$

Low speed setting = ... m s^{-1}

High speed setting = ... m s^{-1} [2]

(b) The ride, with 16 carriages attached, starts out at the low speed setting before it gradually speeds up to the high speed setting. This requires additional energy from the central motor.

(i) Determine the average kinetic energy of each carriage with its rider at the low speed setting.

$$\frac{1}{2}mv_{low}^{2} = 0.5(50.0)(2.50)^2$$
$$= 156 \text{ J}$$

average kinetic energy = ... J [1]

(ii) Determine the gain in gravitational potential energy of each carriage with its rider when the ride goes from the low to the high speed setting.

$$mg\Delta h = (50.0)(9.81)(3.0\cos 5.0 - 3.0\cos 8.0)$$
$$= 8.72 \text{ J}$$

gain in gravitational potential energy = ... J [1]

(iii) Hence, determine the additional energy required for the ride to go from the low to the high speed setting when it is operating at full capacity.

$$\frac{1}{2}mv_{high}^{2} = 0.5(9.81)(3.20)^2$$
$$= 256 \text{ J [1]}$$
$$\Delta E_k + \Delta(\text{grav } E_p) = E_{k,final} - E_{k,initial} + \Delta(\text{grav } E_p)$$
$$= \frac{1}{2}mv_{high}^{2} - 156 + 8.72 \text{ [1 for eqn \& subst.]}$$
$$= 108.47 \text{ J}$$
$$\text{Additional energy for ride} = 16(108.47)$$
$$= 1740 \text{ J [1]}$$

additional energy = ... J [3]

For Examiner's Use

3 **(a)** Define angular velocity for an object travelling in a circle.

Rate of change of angular displacement with respect to time.

[1]

(b) Show, for a circular orbit of a small satellite around a larger mass, that ω, the angular velocity of rotation is related to r, the radius of the orbit by the relationship $\omega^2 \propto r^{-3}$.

Assuming small satellite of mass m orbiting around larger mass M,

By Newton's 2nd Law of motion,

$$\Sigma F = ma_c$$

$$\frac{GMm}{r^2} = m\omega^2 r$$

$$\frac{GM}{r^3} = \omega^2$$

Since GM is a constant, $\omega^2 \propto r^{-3}$. [shown]

[1]

(c) The Lagrangian point is an orbital position where a small object can maintain a stable position relative to two larger bodies. One such point is the Sun-Earth Lagrangian point, L_1, where the satellite Deep Space Climate Observatory (DSCOVR) was launched into. The relative positions of the Sun, Earth and L_1 are shown in Fig. 3.1. At L_1, DSCOVR is able to orbit the Sun with the same angular velocity as Earth, maintaining its position along the Sun-Earth axis throughout its orbit around the Sun.

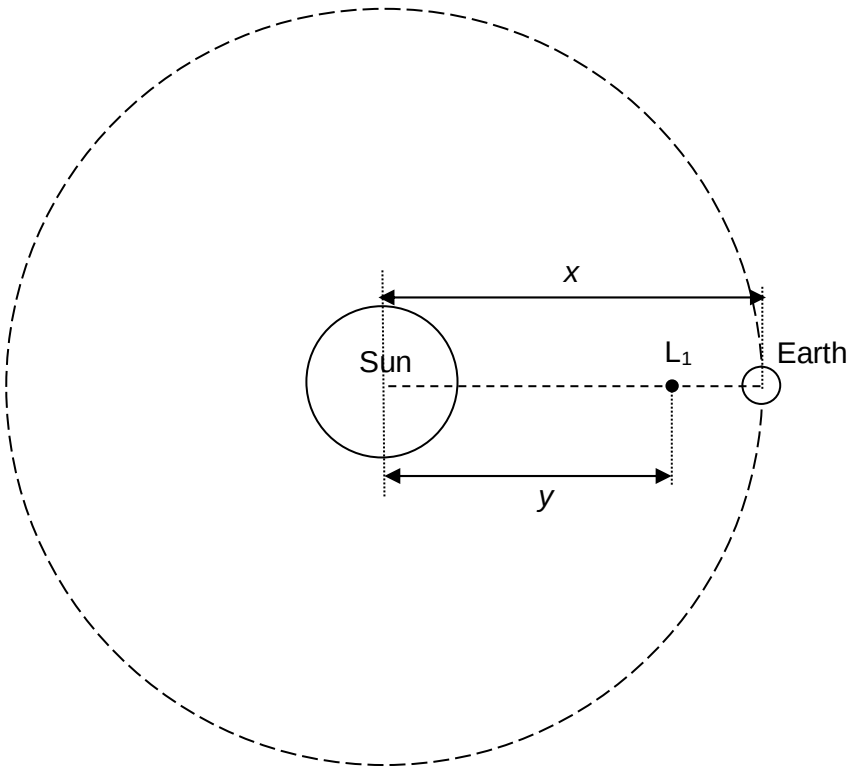


Fig. 3.1

(i) The radius of orbit of DSCOVR at L_1, represented by the distance y, is less than the radius of orbit of Earth, x. Explain why the relationship in **(b)** does not apply to the satellite.

The relationship in (b) is only applicable when the satellite is in the gravitational field of one other mass. The net force providing centripetal acceleration comes only from the gravitational force from that mass. For DSCOVR, the satellite is in the gravitational field of both the Sun and the Earth, both contributing to the net force that results in its circular motion.

[2]

(ii) Hence, or otherwise, show that the relationship of x and y can be represented by the equation

$$\frac{M_S}{y^2} - \frac{M_E}{(x-y)^2} = 5.95 \times 10^{-4}(y)$$

where M_S is the mass of Sun and M_E is the mass of Earth. Explain your working.

By Newton's 2nd Law of motion,

$$\Sigma F = ma_c$$

$$\frac{GM_S m}{y^2} - \frac{GM_E m}{(x-y)^2} = m\omega^2 y$$

$$\frac{M_S}{y^2} - \frac{M_E}{(x-y)^2} = \frac{\omega^2 y}{G}$$

$$= \frac{\left(\frac{2\pi}{T}\right)^2 y}{G}$$

$$= \frac{4\pi^2}{GT^2}(y)$$

$$= \frac{4\pi^2}{6.67 \times 10^{-11}(365 \times 24 \times 3600)^2}(y)$$

$$= 5.95 \times 10^{-4}(y) \quad \text{[shown]}$$

[2]

(iii) The satellite DSCOVR gathers information about the Sun and sends them to a station on Earth. State one advantage and one disadvantage of maintaining the DSCVOR at an orbit at L_1.

Advantage: Advantage: Radiation from the Sun is incident on the satellite at all times, can provide solar power throughout the orbit. Or L_1 provides an equilibrium point for the orbit to take place without the need for additional energy to continually sustain the circular motion. Or any other relevant answers.

Disadvantage: Disadvantage: The equilibrium point at L_1 may not be stable if subjected to other external forces. If additional forces leads to displacement away from the Earth, it may be impossible to retrieve the satellite due to the large force required to do so. Or any other relevant answers.

[2]

For Examiner's Use

4 Fig. 4.1 shows an arrangement for analyzing the light emitted by a point source.

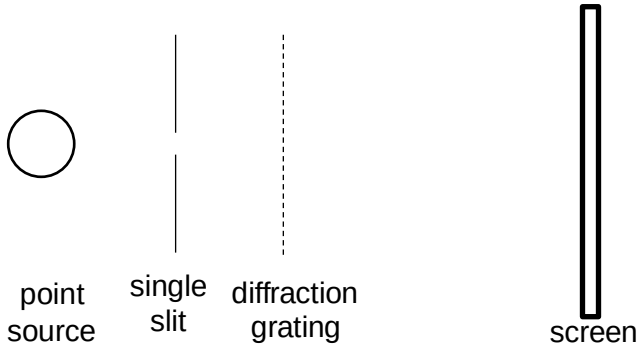


Fig. 4.1

(a) Suggest a light source that would emit a continuous spectrum.

Filament lamp/sun etc.

..... [1]

(b) The light source emits a range of wavelengths from 500 nm to 700 nm. The light is incident on a diffraction grating that has 10 000 lines per centimetre.

(i) Calculate the angle from the straight-through direction at which the first order maximum for the 500 nm wavelength is formed.

$$d = \frac{10^{-2}}{10000}$$
$$= 1.0 \times 10^{-6} \text{ m}$$
$$d \sin\theta = n\lambda$$
$$\theta = 30.0°$$

angle = ... ° [2]

(ii) Calculate the angular separation of the first order spectrum.

$\Delta\theta = 14.4°$

angular separation = ... ° [2]

(iii) The screen is positioned 2.0 m from the grating. Calculate the width of the first order spectrum on the screen.

$$w = 2(\tan 44.4° - \tan 30.0°)$$
$$= 0.806 \text{ m}$$

width = ... m [2]

(iv) Describe the pattern which would be observed.

Two continuous first order spectra are observed on each side of the zeroth order on the screen with the zeroth order the superposition of all the wavelengths ranging from 500 nm to 700 nm.

..... [1]

For Examiner's Use

5 Fig. 5.1 shows a simple electric motor made up of an armature placed between two permanent magnets. The armature consists of a single square coil of copper wire of resistance 0.50 Ω.

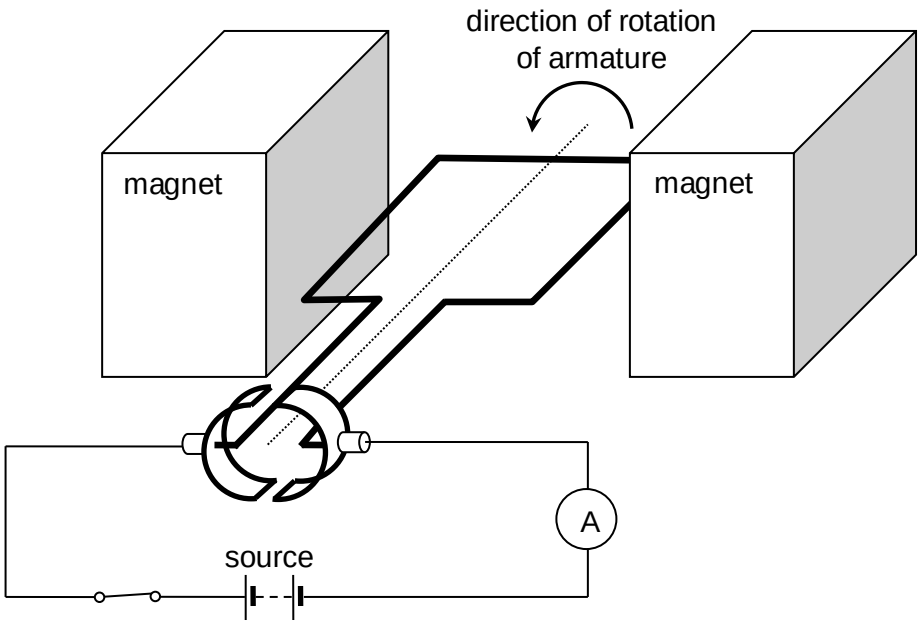


Fig. 5.1

The armature carries a current of 0.55 A just before it starts to move from the position as shown in Fig. 5.1.

(a) The current through the armature falls to below 0.55 A once the motor starts rotating. Explain why this is so.

As the motor starts rotating, the area normal to the magnetic field changes, hence there is a change of magnetic flux linkage through the armature. [B1]

By Faraday's law, which states that the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage, an e.m.f. will be induced in the armature. [B1]

By Lenz's law, the current due to the induced e.m.f. will oppose the change in magnetic flux linkage [B1] and will hence flow in the direction opposite to the current from the source, reducing the overall current through the armature [B1].

[4]

(b) When the armature is rotating at a constant rate, the minimum current in the armature decreases to 0.14 A. Calculate the maximum rate at which the magnetic flux linkage through the armature changes.

Maximum current due to induced e.m.f. $I = 0.55 - 0.14 = 0.41$ A

Maximum induced e.m.f. $\varepsilon = 0.41 \times 0.50 = 0.205$ V [M1]

$\left.\frac{d\phi}{dt}\right|_{max} = \varepsilon_{max}$ [B1]

$= 0.205$ Wb s^{-1} [A1]

maximum rate = ... Wb s^{-1} [3]

6 **(a)** One property of a laser is that it can direct a large amount of energy onto a very small spot. In one particular application, the laser emits a 3.0 mJ pulse in 1.0 ns, focused on a spot 8.0 × 10^{-10} m^2 in area. Calculate the power per unit area at the target. [2]

Power per unit area = 3.0 x 10^{-3} / 1.0 x 10^{-9} / 8 x 10^{-10} W m^{-2} = 3.8 x 10^{15} W m^{-2}

(b) Using the ideas of population inversion and stimulated emission, explain how a laser could deliver an intense and directed light beam. [4]

When there are **more atoms in a higher state than in a lower state**, population inversion occurs. Population inversion is achievable if sufficient and continuous energy is provided to excite these atoms. [1]

Stimulated emission is the emission of a photon of frequency *f* from an excited atom **triggered by another photon of the same frequency *f***. [1] The emitted photon and the incident photon that stimulated its emission then move off **in phase in the same direction**. Hence, photons emitted via stimulated emission are **coherent**. [1 for either]

Stimulated emission together with population inversion allows a **cascade of photons** / **many photons** to be emitted at the same time (in phase), [1] hence producing an intense beam (Allow mention of reflecting mirrors enabling photon retention for a more intense beam)

For Examiner's Use

7 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.

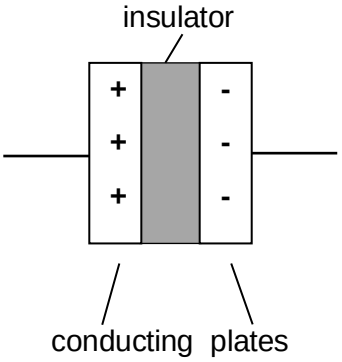


Fig. 7.1

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) The capacitor is now charged. Fig. 7.2 shows the values of potential difference V and the corresponding amount of charge Q.

***V*/ V**	***Q*/ μC**
0.4	1.9
1.3	6.1
2.5	14.3
3.3	15.5
4.2	19.7
5.1	23.5

Fig. 7.2

For Examiner's Use

(i) On Fig. 7.3, sketch a line to show the variation of the amount of charge *Q* with the potential difference *V* between the plates. [1]

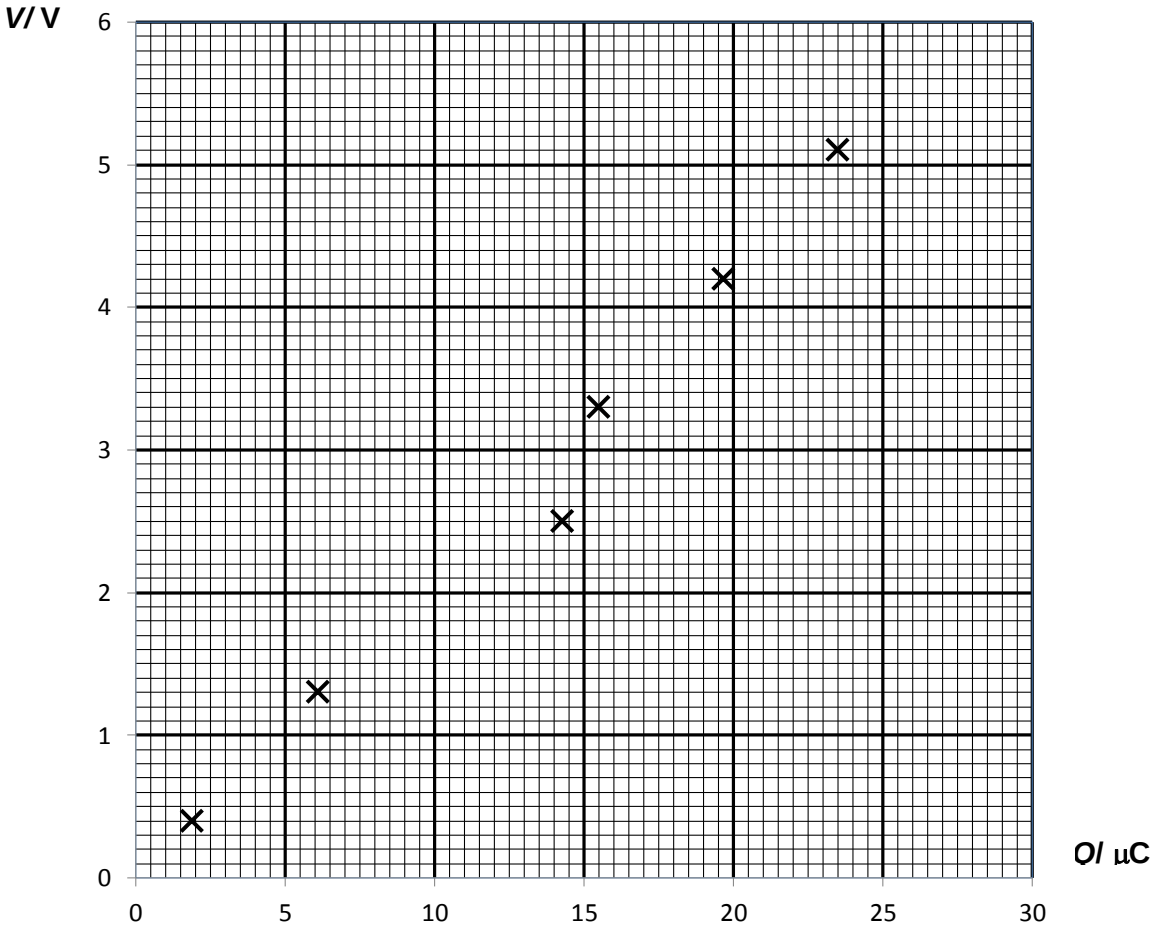


Fig. 7.3

(ii) State the quantity represented by the

1. gradient of the line,

..... [1]

1/C or reciprocal of capacitance C. [1]

2. area under the line.

..... [1]

Electric energy stored in capacitor [1]

(iii) Hence show that the energy *E* stored in a capacitor is ½ CV^2.

Area = ½ Q V [1]

= ½ CV^2

For Examiner's Use

[1]

(b) The capacitor is now discharged by connecting it across a resistor of resistance *R*. Fig. 7.4 shows the variation with time *t* of the potential difference *V* across the resistor.

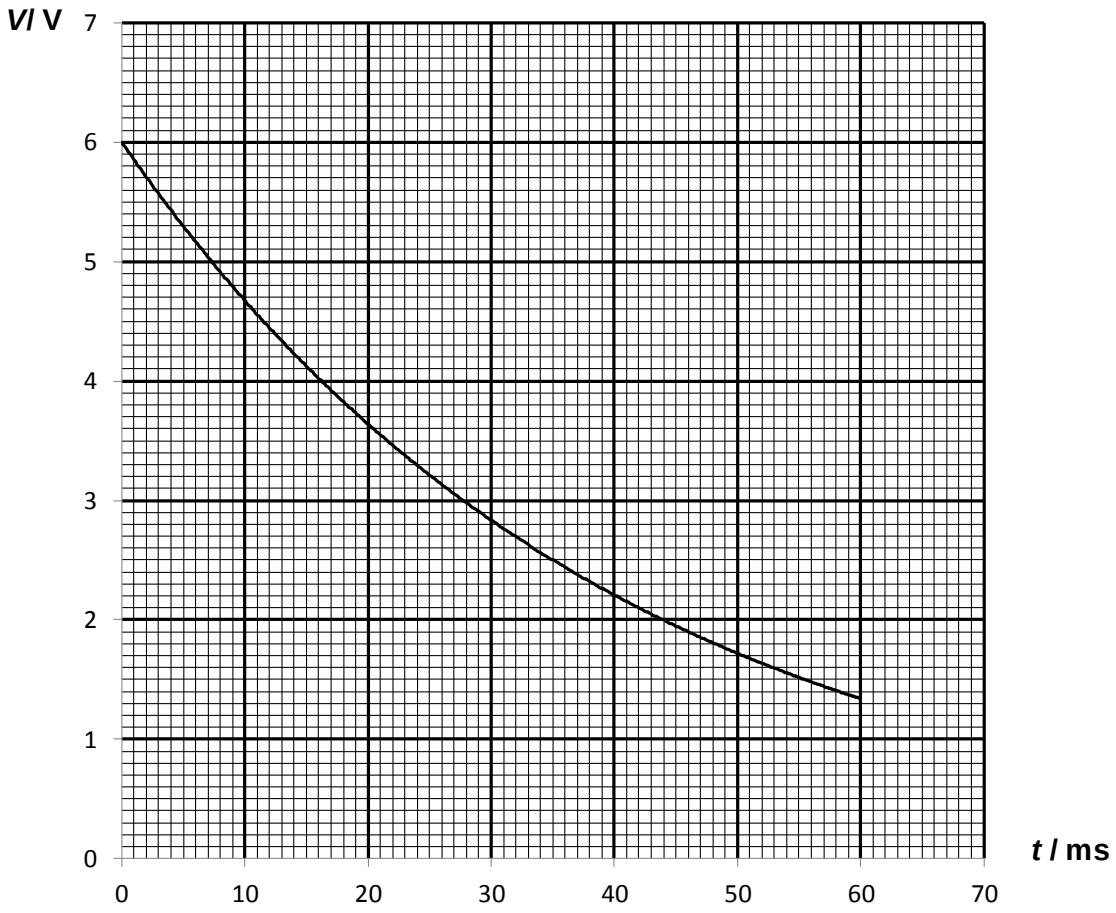


Fig. 7.4

(i) **1.** Using Fig. 7.3 and Fig. 7.4, determine the initial amount of charge stored.

From fig 7.4, at t = 0, V = 6.00 V. [1]

From fig 7.3, read of best fit line. At 6.00 V, Q = 27.7 μC [1]

charge = ... C [2]

2. Calculate the capacitance *C*.

Q = CV

C = Q/V = $27.7 \times 10^{-6} / 6.00 = 4.61 \times 10^{-6}$ [1]

capacitance = ... C V^{-1} [1]

(iii) Calculate the energy lost when the capacitor has been discharged for 45 ms.

At 45 ms, V = 1.92 V [1]

Energy lost = ½ C ($V_i^2 - V_f^2$)

= ½ x 4.61 x 10^{-6} ($6.00^2 - 1.92^2$) [1]

= 7.45 x 10^{-5} J [1]

energy lost = ... J [3]

(b) When discharging through the resistor of resistance *R*, the variation of the potential difference *V* with time *t* is given by the following equation:

$$V = V_o e^{-t/RC}$$

(i) Deduce the base units of C.

[RC] = [τ]

[C] = [τ]/[R] = [τ][I]/[V] = [τ][Q/t]/[W/Q] = [τ][Q^2/t]/[W] [1]

= $A^2 s^2$ /kg $m^2 s^{-2}$ = $A^2 kg^{-1} m^{-2} s^4$ [1]

Or

[Q] = [CV]

[C] = [Q]/ [V] = [Q]/ [W/Q] = [Q^2]/ [W] [1]

= $A^2 s^2$/kg m^2 s^{-2} = $A^2 kg^{-1} m^{-2} s^4$ [1]

base units = ... [2]

(ii) State how the value of *RC* affects the rate of discharge.

.....

..... [1]

A greater value of *RC* slows down the rate of discharge. [1]

(d) Fig 7.5 shows an A.C. supply connected to resistor-capacitor (RC) circuit containing an ideal diode. Fig 7.6 shows the potential difference measured by the CRO.

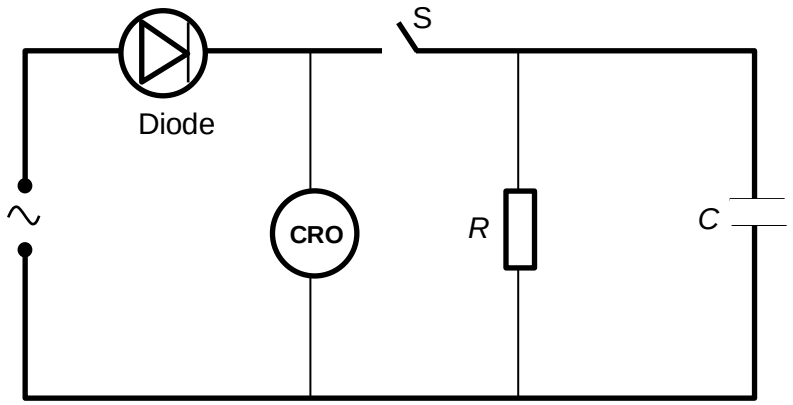


Fig. 7.5

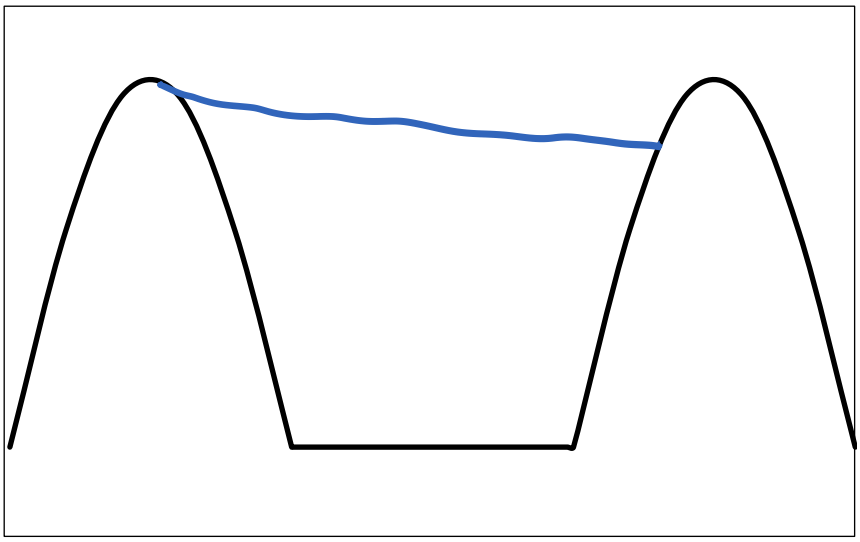


Fig. 7.6

Switch S is now closed.

(i) Sketch on Fig. 7.6, the expected display on the CRO. [1]

(ii) State one possible application of the RC circuit.

.....

..... [1]

Smooth the ripples of a half wave rectified signal. [1]

8 Gamma radiation is often used to kill living micro-organisms, in a process called irradiation. Applications of this include sterilizing medical equipment, removing decay-causing bacteria from food or preventing fruits and vegetables from sprouting to maintain freshness and flavour.

Despite their cancer-causing properties, gamma rays are also used to treat some types of cancer since the rays kill cancer cells too. In a procedure called gamma knife surgery, multiple concentrated beams of gamma rays are directed on the growth in order to kill the cancerous cells.

A student wishes to investigate how different thicknesses of lead absorbers affect the count rate from a radioactive gamma source in his school science laboratory. He was told by his Physics teacher that the count rate C obeys the equation:

$$C = C_0 e^{-\mu x}$$

where x is the thickness of the lead absorbers, and C_o is a constant.

Design a laboratory experiment to verify this equation and determine the value of the constant μ.

You may assume that the following equipment is available, together with any other apparatus that may be found in a school or college science laboratory:

Ammeter Voltmeter	
Connecting wires	Variable d.c. power supply
Lead plates of different thicknesses	Geiger-Müller tube
Oscilloscope	Datalogger
Ratemeter	Signal generator
Source handling tool	Metre rule

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

(a) the equipment you would use for the investigation,

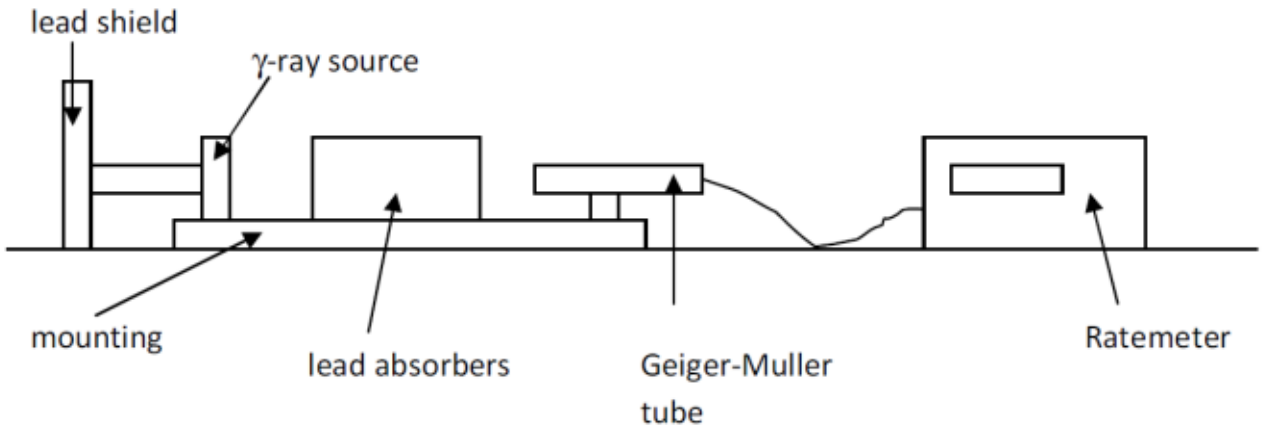
(b) the procedure to be followed, including how the count rate would be measured,

(c) the control of variables,

(d) any safety precautions you would take.

(e) any precautions that you would take to improve the accuracy of the experiment.

[12]



Methods of data collection [5 marks]
- GM tube connected to ratemeter/data logger (from diagram)
- Correct placement of source, lead absorbers and GM tube (from diagram)
- Determine count rate by taking total count (measured using ratemeter) divided by exposure time (measure using stopwatch)
- Determine C_{BG} with relevant details and minus it with C_{raw} to obtain C_{actual}.
- Vary and measure the thickness of lead absorbers using Vernier calipers/micrometer screw gauge. Meter rule is not allowed.

Method of analysis [2 marks]
- Appropriate graph of the dependent variable against the independent variable is to be plotted to obtain a straight line (i.e. ln C_{actual} against x)
- μ is equal to the negative of the gradient

Safety considerations [max 1 marks]
- Keep radioactive source within a lead container at all times
- Use a pair of tongs at all times when handling the radioactive source

Additional Details [max 4 marks]
- Distance between source and GM tube/Orientation of the source opening and GM tube.
- Suitable means to absorb α and β particles (e.g. using aluminum sheets or Electric field) before radiation passing through steel. (to ensure that all counts are purely due to gamma radiation)
- Check if the y-intercept of ln C_0 tallies with the C_0 when no lead absorber is placed
- Select a radioactive source with a long half life (so that the activity will not drop significantly during the experiment)
- Movement or rotation of tube to get maximum count rate for more accurate reading
- Takes an average of measurements for x and/or C and find the average value.
- Preliminary trials to be conducted to ascertain the maximum thickness of steel plate to be used (count rate should still be significantly higher than the background count).

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9646/01**
Higher 2

Paper 1 Multiple Choice

23 September 2016

1 hour 15 minutes

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 **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 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 **21** printed pages.

Data

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

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,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
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,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 A cylindrical tube rolling down a slope of inclination θ moves a distance *L* in time *T*. The equation relating these quantities is

$$L\left(3+\frac{a^2}{P}\right)=QT^2\sin\theta$$

where *a* is the internal radius of the tube and *P* and *Q* are constants.

Which of the following gives the correct units for *P* and *Q*?

	units of *P*	units of *Q*
A	m	$m\,s^{-2}$
B	m^2	$m\,s^{-2}$
C	m^2	$m^3\,s^{-2}$
D	m^2	$m^2\,s^{-2}$

2 A fighter-bomber flies towards a target at a speed of 750 $km\,h^{-1}$. At a height of 500 m above the ground, it releases a 150 kg bomb while diving at an angle of 20° below the horizontal.

How far ahead of the target horizontally must the bomb be released?

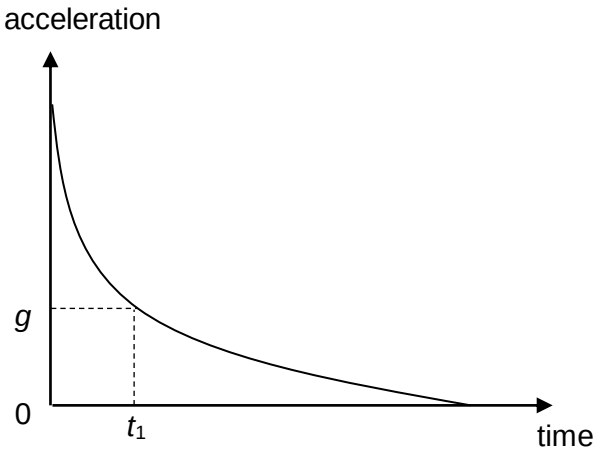
A 170 m

B 1000 m

C 3000 m

D 3800 m

3 A light plastic ball is thrown vertically up into the air. The graph below shows the variation of acceleration with time of the ball. At time t_1, the acceleration of the ball is equal to the acceleration of free fall, g.



Which of the following statements about the motion of the ball is correct?

A t_1 is the time taken for the ball to reach its maximum height.

B t_1 is the time taken for the ball to fall back to its original height.

C The time taken for the ball to reach its maximum height is shorter than t_1.

D The time taken for the ball to fall back to its original height is shorter than t_1.

4 An object of mass 2.0 kg is moving on a smooth horizontal surface with a speed of 1.41 $m s^{-1}$ in a north-easterly direction. A constant force of 0.20 N acts on the object in a easterly direction for 10 s.

What is the final velocity of the object?

A 0.71 $m s^{-1}$ in a northerly direction

B 1.00 $m s^{-1}$ in a northerly direction

C 1.58 $m s^{-1}$ in a direction 71.6° East of North

D 2.23 $m s^{-1}$ in a direction 63.5° East of North

5 A helicopter of mass 1000 kg accelerates vertically upwards due to the vertical lift force generated by its rotating blades. It starts from rest and travels a vertical distance of 50 m in 4.0 s.

To enable the helicopter to fly forward in a horizontal straight line, the helicopter is now tilted such that its lift force is at an angle of 52° to the vertical. The magnitude of the lift force remains constant.

Ignoring air resistance, what is the forward horizontal acceleration of the helicopter?

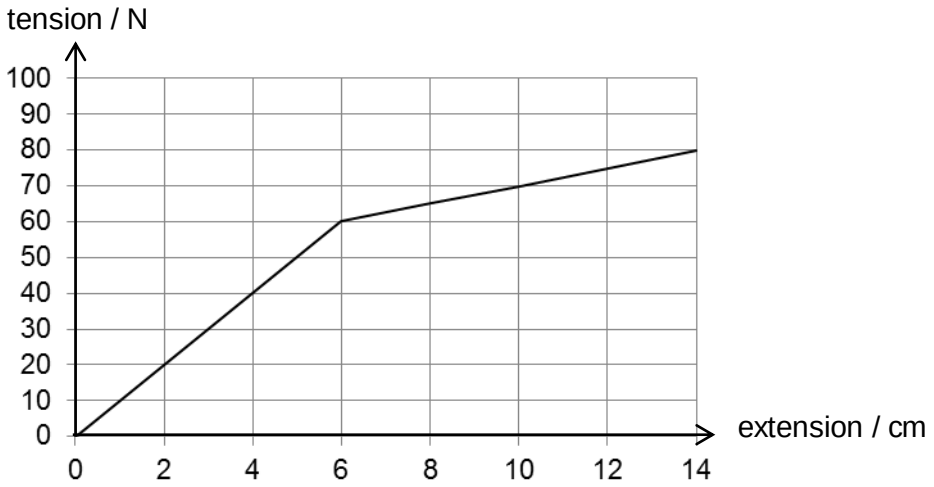
A 3.4 $m s^{-2}$

B 8.6 $m s^{-2}$

C 13 $m s^{-2}$

D 16 $m s^{-2}$

6 A sample is placed in a tensile testing machine. The graph below shows the variation of the tension applied on the sample with its extension.



What is the extension in the sample when the work done on it is 4.4 J?

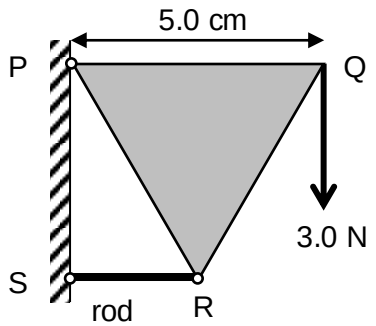
A 7.0 cm

B 9.4 cm

C 10 cm

D 12 cm

7 An equilateral triangle PQR of mass 100 g is mounted on a smooth wall using a hinge at P as shown in the figure below. PQ has a length of 5.0 cm, and is horizontal. A rod is hinged to R and S, such that the rod is horizontal. A downward force of 3.0 N is applied at Q, and the system is in equilibrium.



What is the magnitude of the horizontal force exerted by the wall on the rod at S?

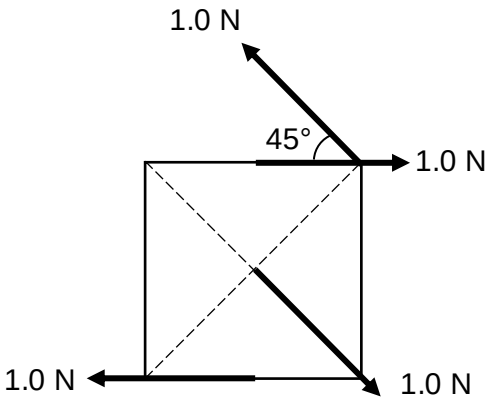
A 2.5 N

B 3.5 N

C 4.0 N

D 4.6 N

8 The figure below shows forces acting on a piece of square cardboard of negligible mass in a single plane. The cardboard has a length of 5.0 cm on each side.



Which of the following statements is true?

A The cardboard is not in equilibrium.

B The cardboard is in rotational equilibrium.

C The cardboard is not in translational equilibrium.

D The cardboard will rotate in an anticlockwise direction.

9 An electric motor is required to haul a cage of mass 400 kg up a mine shaft at constant speed through a vertical height of 1200 m in 2.0 minutes.

Given that the overall efficiency of the motor is 80%, what is the total power wasted?

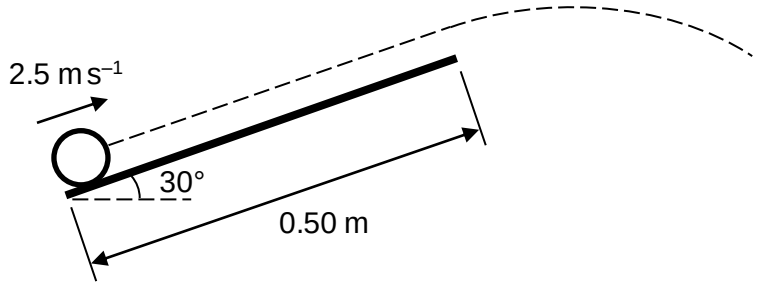
A 7.8 kW

B 9.8 kW

C 39 kW

D 49 kW

10 A ball of mass 200 g is projected up a smooth inclined plane of length 0.50 m, at an angle of 30° above the horizontal, with an initial speed of 2.5 $m s^{-1}$. The ball leaves the plane and then moves in a projectile motion.



Assuming that the air resistance is negligible, what is the minimum kinetic energy of the ball during its flight?

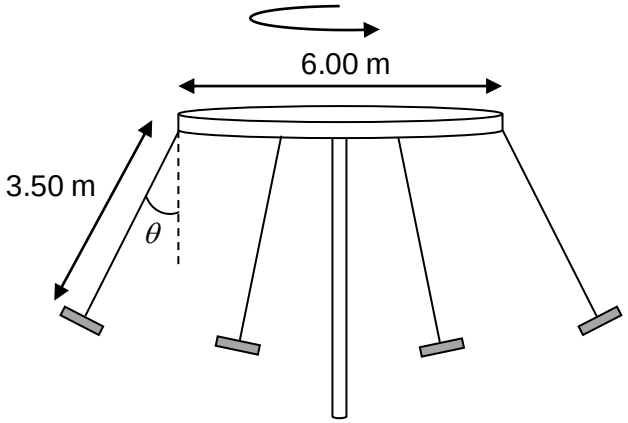
A 0 J

B 0.10 J

C 0.13 J

D 0.47 J

11 An amusement park ride consists of a rotating circular platform 6.00 m in diameter from which 10.0 kg seats are suspended at the end of 3.50 m cables, as shown in the figure. When the seats rotate at a constant speed *v*, the cables make an angle of $\theta = 30.0°$ with the vertical.



What is the speed *v* at which the seats are moving?

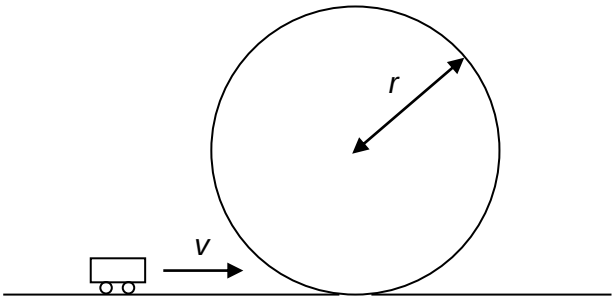
A 3.15 m s^{-1}

B 4.97 m s^{-1}

C 5.19 m s^{-1}

D 5.84 m s^{-1}

12 A roller coaster of mass *m* moves in a vertical circle of radius *r*.



At what minimum speed *v* must the roller coaster be travelling at the bottom of the circle so that the ride is safe?

A $\sqrt{rg}$ **B** $\sqrt{3}\sqrt{rg}$ **C** $2\sqrt{rg}$ **D** $\sqrt{5}\sqrt{rg}$

13 Two stationary particles of masses M_1 and M_2 are at a distance r apart. A third particle, lying on the line joining the particles, experiences no resultant gravitational force.

What is the distance of this particle from M_1?

A $r\sqrt{\left(\frac{M_1}{M_2}\right)}$

B $r\left(\frac{M_1}{M_1+M_2}\right)$

C $r\sqrt{\left(\frac{M_1}{M_1+M_2}\right)}$

D $r\left(\frac{\sqrt{M_1}}{\sqrt{M_1}+\sqrt{M_2}}\right)$

14 A rocket is orbiting around the Earth with a tangential velocity of v. The orbit has a gravitational potential of $-30\ \text{MJkg}^{-1}$. The boosters are fired and the rocket moves to a new orbit of gravitational potential $-10\ \text{MJkg}^{-1}$.

What is the velocity of the rocket in the new orbit?

A $\frac{v}{\sqrt{3}}$

B $\frac{v}{3}$

C $\sqrt{3}v$

D $3v$

15 An object undergoes a simple harmonic motion with an amplitude A, and its total energy is E.

What is the displacement of the object from the equilibrium position when its kinetic energy is $\frac{3E}{4}$?

A $\frac{A}{4}$

B $\frac{A}{2}$

C $\frac{3A}{4}$

D $\frac{A\sqrt{3}}{2}$

16 A particle undergoes simple harmonic motion with zero damping.

Which of the following quantities of the particle may not change if it undergoes light damping after some time ?

A total energy

B maximum speed

C amplitude of oscillation

D frequency of oscillation

17 Ice of mass m at 0 °C is added to water of mass m at 80 °C. The specific latent heat of fusion of ice and specific heat capacity of water are $3.3\times10^{5}\ \text{J kg}^{-1}$ and $4.2\times10^{3}\ \text{J kg}^{-1}\text{K}^{-1}$ respectively.

Assuming that there is no heat loss to the environment, what is the final temperature of the mixture?

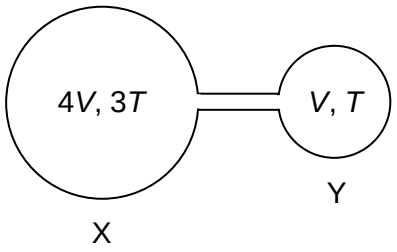
A 0.71 °C

B 1.4 °C

C 20 °C

D 40 °C

18 An ideal gas is contained in two spherical containers X and Y of volume $4V$ and V respectively, connected by a hollow tube of negligible volume. The containers X and Y are maintained at temperatures $3T$ and T respectively. The setup is shown in the diagram below.



What is the ratio $\frac{\text{amount of gas in moles in container X}}{\text{amount of gas in moles in container Y}}$?

A 1 : 4

B 4 : 1

C 3 : 4

D 4 : 3

19 A bicycle tyre contains air of volume 2.0×10^{-4} m^3 at a temperature of 300 K and pressure of 250 kPa.

If a cyclist brings the pressure up to 350 kPa without changing the temperature, what is the amount of air, in moles, that must be pumped into the tyre?

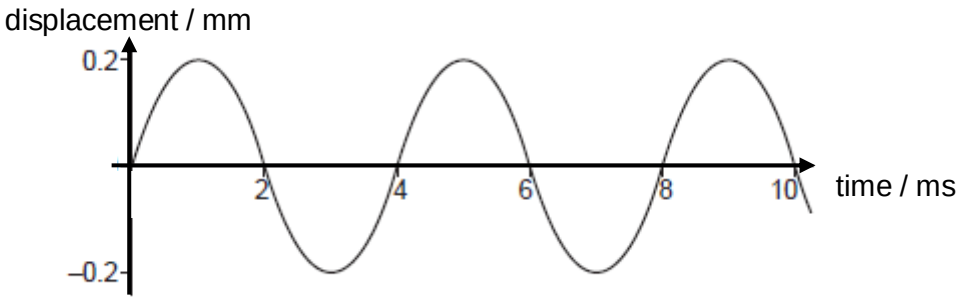
A 0

B 0.0080

C 0.020

D 0.028

20 A sound wave moves with a speed of 320 m s^{-1} through air. The variation with time of the displacement of an air particle due to this wave is shown in the graph.



Which statement about the sound wave is correct?

A The frequency of the wave is 500 Hz.

B The wavelength of the sound wave is 1.28 m.

C The graph shows that sound is a transverse wave.

D The intensity of the wave will be doubled if its amplitude is increased to 0.4 mm.

21 Which of the following is not an essential condition for an observable interference pattern to occur between the waves from two sources?

A The sources must be coherent.

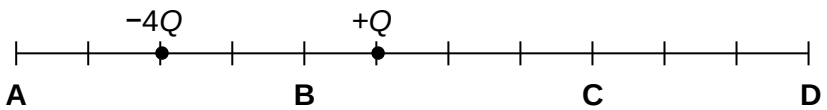
B The waves from the two sources must overlap.

C The sources must emit waves of equal amplitude.

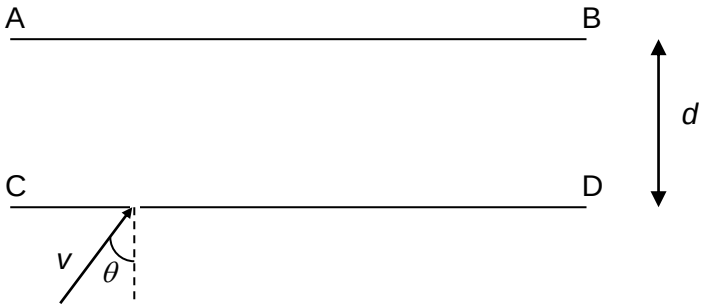
D The frequencies of the two sources must be equal.

22 Two point charges −4*Q* and +*Q* are situated as shown.

At which point could the electric force experienced by any charge *q* be zero?



23 The figure below shows two 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 as shown in the figure.



Given that the electron charge is $-e$ and the electron mass is m_e, the electrons will just reach AB if

A $\frac{1}{2}m_e v^2 = \frac{e}{4\pi\varepsilon_o d}$.

B $\frac{1}{2}m_e v^2 = eV$.

C $\frac{1}{2}m_e (v\cos\theta)^2 = eV$.

D $\frac{1}{2}m_e (v\sin\theta)^2 = eV$.

24 The charge that an electric battery can deliver is specified in ampere-hours.

For example, a battery of capacity 50 ampere-hours could supply, when fully charged, 0.25 A for 200 hours.

What is the maximum energy that a fully charged 12 V, 50 ampere-hour battery could supply?

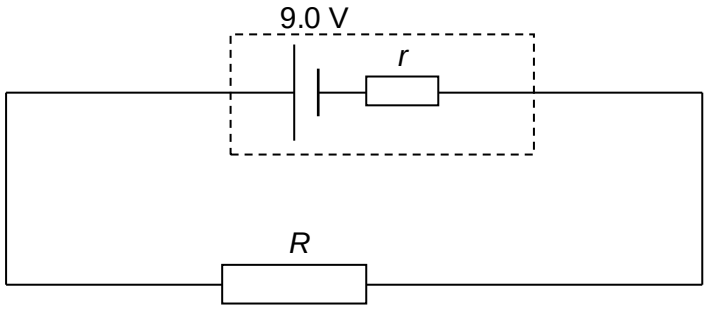
A 600 J

B 36000 J

C 120000 J

D 2160000 J

25 A circuit is formed by connecting a resistor of resistance *R* between the terminals of a battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r*.



A charge of 6.0 C flows through the resistor in a time of 2.0 minutes causing it to dissipate 48 J of thermal energy.

What is the internal resistance *r* of the battery?

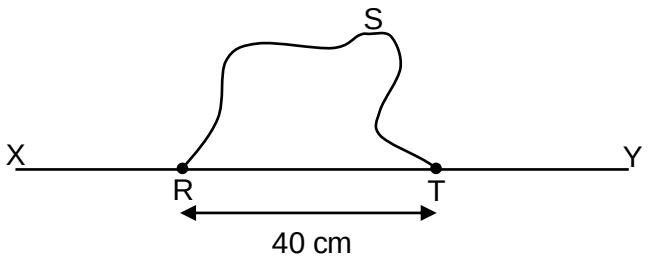
A 1.3 Ω

B 20 Ω

C 160 Ω

D 180 Ω

26 A wire RST is connected to another wire XY as shown.



Each wire is 120 cm long with a resistance per unit length of 8.0 Ω m^{-1}.

What is the total resistance between X and Y?

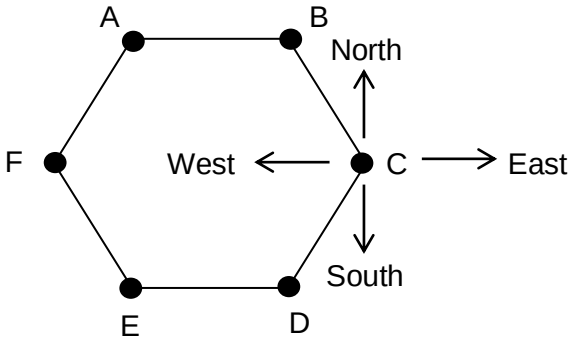
A 2.7 Ω

B 4.8 Ω

C 8.8 Ω

D 13.6 Ω

27 Six vertical conductors are placed at the corners of a regular hexagon ABCDEF as shown below. Each conductor at A, B, C, D and E carries equal currents in the same direction perpendicular to the plane of the paper. The conductor at F carries current of the same magnitude but in the opposite direction.



Ignoring the Earth's magnetic field, in which direction is the net force on the conductor at C due to the other conductors?

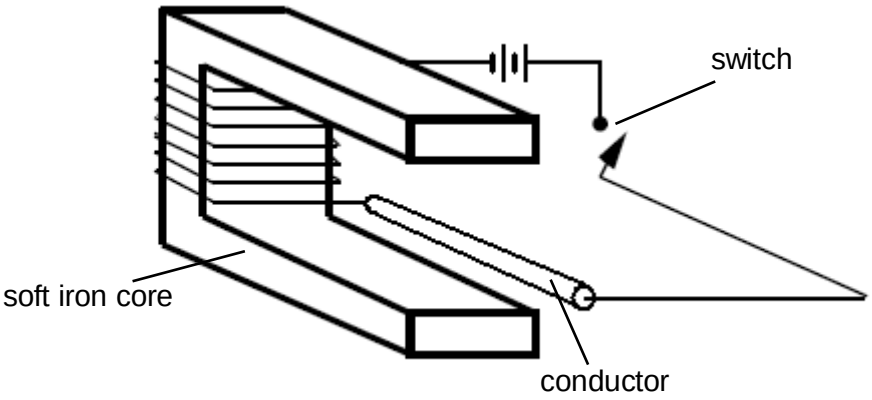
A North

B South

C East

D West

28 A straight conductor rests in the space between two arms of a soft iron core.



After the switch has been closed for a while, in which direction is the magnetic force acting on the conductor?

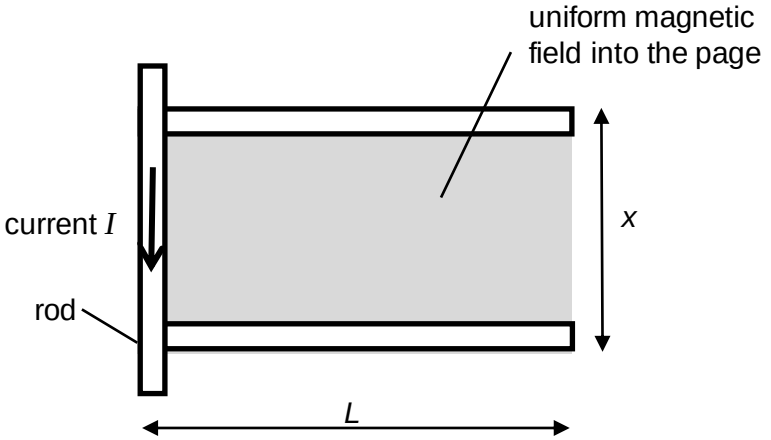
A up

B down

C left

D right

29 A rod of mass *m* and length 1.5*x* rests on two parallel rails placed a distance *x* apart. Each rail has length *L*, resistivity ρ and cross sectional area *A*. A potential difference of *V* is applied across the two ends of the rod and a current of I flows in the direction shown.



What is the initial acceleration of the rod if there is a uniform magnetic field *B* directed into the page?

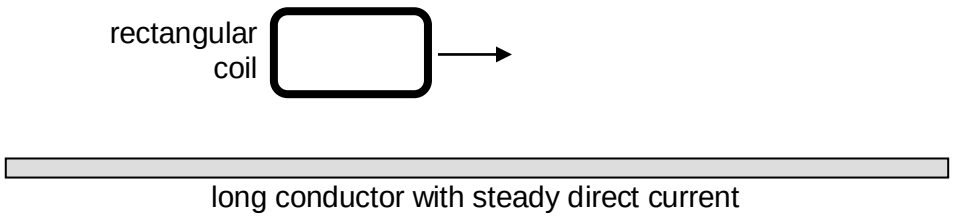
A $\frac{BVAx}{2m\rho L}$

B $\frac{3BVAx}{4m\rho L}$

C $\frac{BIx}{m}$

D $\frac{3BIx}{2m}$

30 A rectangular coil moves in the direction parallel to a long straight current-carrying conductor as shown below. The conductor carries a steady direct current.



Which of the following statements is true?

A There is no induced current in the coil.

B The induced current flows clockwise in the coil.

C The magnitude of the induced current decreases with the coil's distance from the conductor.

D The magnitude of the induced current in the coil varies with the speed at which the coil is moving.

31 A sinusoidal current of peak value 5 A is passed through a resistor of resistance 5 Ω with a diode connected in series with it.

What is the average rate of heat dissipated in the 5 Ω resistor?

A 5 W

B 10 W

C 20 W

D 30 W

32 What is the purpose of using a soft-iron core in an ideal transformer?

A to reduce heat loss through eddy current

B to produce a uniform magnetic field in the two coils

C to improve the flux linkage between the primary and secondary coils

D to improve the flux density between the primary and secondary coils

33 When electromagnetic radiation of frequency *f* irradiates a metal surface, electrons are emitted and the measured stopping potential is V_s.

The frequency of the incident radiation is halved to $\frac{f}{2}$.

What change occurs in the stopping potential?

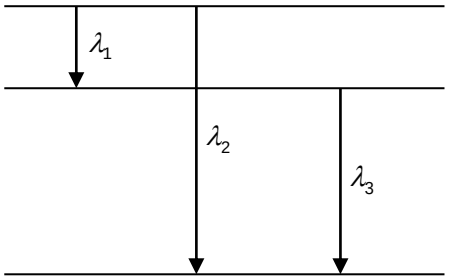
A The stopping potential remains at V_s.

B The stopping potential decreases to $\frac{V_s}{2}$.

C The stopping potential decreases to less than $\frac{V_s}{2}$.

D The stopping potential decreases to more than $\frac{V_s}{2}$.

34 Transitions between three energy levels in a particular atom give rise to three spectral line of wavelengths λ_1, λ_2 and λ_3.



Which of the following statements is correct?

A The radiation with wavelength λ_2 has the smallest energy.

B The equation that relates the wavelengths is given by $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} - \frac{1}{\lambda_3}$.

C λ_1 is the shortest wavelength of the emitted electron which has the largest momentum.

D The transitions give rise to an emission spectrum where dark lines are observed on a coloured background.

35 An electron is incident on a rectangular potential barrier with a kinetic energy of 2.0 eV. The barrier height is 6.0 eV and its width $d = 2.0 \times 10^{-10}$ m. The probability of the electron tunnelling through the barrier is T.

What would be the probability in terms of T if the barrier width is reduced to 0.8×10^{-10} m?

A $T^{0.4}$ **B** $T^{0.8}$ **C** $0.45T$ **D** $0.67T$

36 Stimulated emission occurs in the laser when a photon X causes the emission of a photon Y.

Which of the following statements is false of the photons?

A They possess the same momentum.

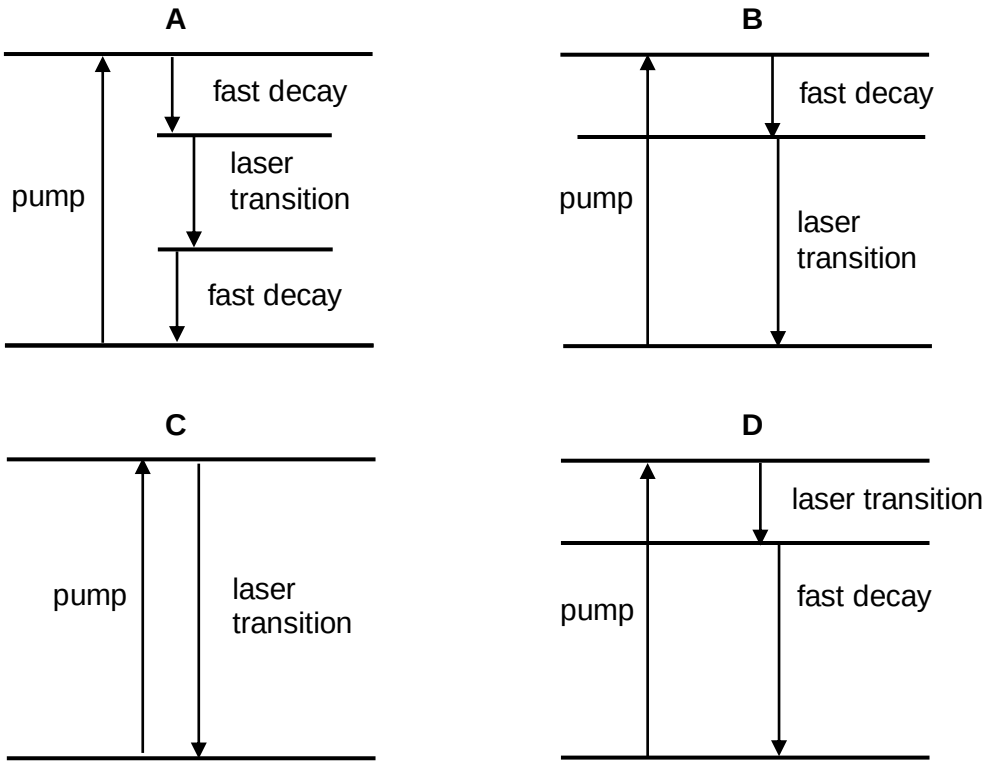
B They have the same quanta of energy.

C They are polarised in the same direction.

D They have different frequencies but are in phase and travelling in the same direction.

37 Below are energy level schemes of possible laser materials. The "pump" is where excitation takes place. The "laser transition" indicates the transition where lasing should occur. The transition "fast decay" is fast compared to the pumping or excitation process as well as the lasing transition.

Which of these level schemes is the least efficient in facilitating for population inversion?



38 Which of the following statements is false?

A The charge carriers supporting electrical conduction for metals are electrons.

B The charge carriers supporting electrical conduction for intrinsic semiconductors are holes and electrons.

C The minority charge carriers supporting electrical conduction for p-type semiconductors are holes.

D The majority charge carriers supporting electrical conduction for n-type semiconductors are electrons.

39 A nuclide undergoes combinations of radioactive decay so that the final nuclide produced is an isotope of the original one.

Which of the following radioactive decays is correct?

A α and β

B α and 2β

C α and 4β

D 2α and β

40 A radioactive source contains two samples X and Y. Sample X has a half-life of 4 days and decays by the emission of alpha particles, while sample Y has a half-life of 3 days and emits beta particles. The initial count-rate is 352 min^{-1}, but when a sheet of paper is placed between the source and the detector, this becomes 256 min^{-1}. The background count-rate is 16 min^{-1}.

What will be the count-rate after 12 days, without the paper present?

A 27 min^{-1}

B 28 min^{-1}

C 43 min^{-1}

D 44 min^{-1}

End of paper

Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9646/02**
Higher 2

Paper 2 Structured Questions

16 September 2016

1 hour 45 minutes

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		/	6
2		/	8
3		/	8
4		/	8
5		/	6
6		/	8
7		/	16
8		/	12
Total		/	72

This document consists of **20** printed pages.

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}

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,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
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,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** The drift velocity *v* of electrons is related to the current I, number of electrons per unit volume *N*, cross-sectional area *A* of wire and charge *Q* by the equation

$$v = \frac{kI}{NAQ},$$

where *k* is a dimensionless constant.

(i) Explain what is meant by a dimensionless constant.

.....

..... [1]

(ii) Show that *k* is dimensionless.

[2]

(b) The volume flow rate $\frac{V}{t}$, of a fluid under streamline conditions through a horizontal pipe of length *L* and radius *r* is

$$\frac{V}{t} = \frac{\pi p r^4}{8LW},$$

where *p* is the pressure difference across the pipe and *W* is a property of the fluid.

In an experiment to determine *W* for water, a student obtains 1.137×10^{-3} kg m^{-1} s^{-1} for *W* and estimates the percentage uncertainties in his measurements of $\frac{V}{t}$, *p*, *L* and *r* as ±3%, ±2%, ±0.5% and ±5% respectively.

Express the value of *W*, together with its associated uncertainty to the appropriate number of significant figures.

W = ... ± ..... kg m^{-1} s^{-1} [3]

2 **(a)** State the origin of upthrust acting on a body in a fluid.

.....

.....

..... [2]

(b) Fig. 2.1 shows a tank filled with water. An object of volume 50 cm^3 and density 850 kg m^{-3} is released from rest at the bottom of the tank. At a height of 10 cm from the bottom of the tank, it has an instantaneous velocity *v*. It is assumed that there are no drag forces acting on the object by the water, and that the density of water is 1000 kg m^{-3}.

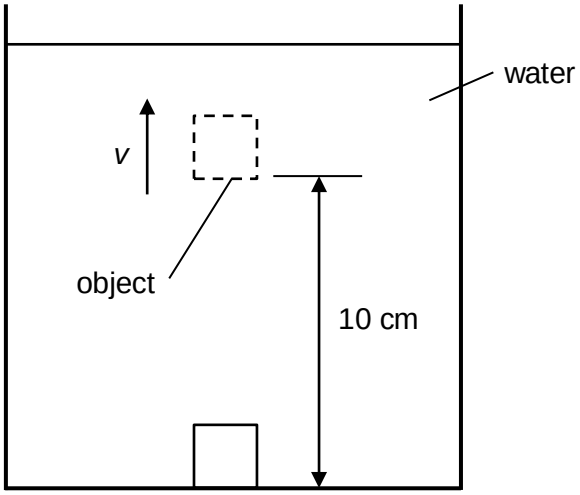


Fig. 2.1

(i) Determine the work done on the object due to the upthrust.

work done = ... J [2]

(ii) Hence, determine the value of v using the principle of conservation of energy**.**

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

(iii) In practice, there are drag forces acting by the water against the object as it moves upwards.

Discuss how the value of v in **(b)(ii)** will be affected in this situation.

.....

.....

..... [2]

3 Fig. 3.1 shows two loudspeakers P and Q connected to a signal generator, emitting sound of a single frequency. A person walks in the direction from O to Y. The line OY is at a distance *D* from the loudspeakers and point O is equidistant from loudspeakers P and Q.

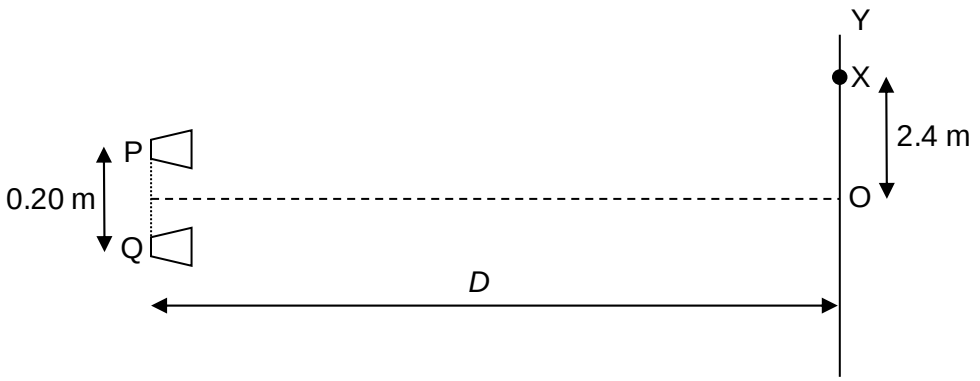


Fig. 3.1

The sound waves emitted by P and Q have displacements x_P and x_Q respectively at point X. Fig. 3.2 shows the variation with time *t* of each of these displacements. Point X is the position of the first minimum from point O.

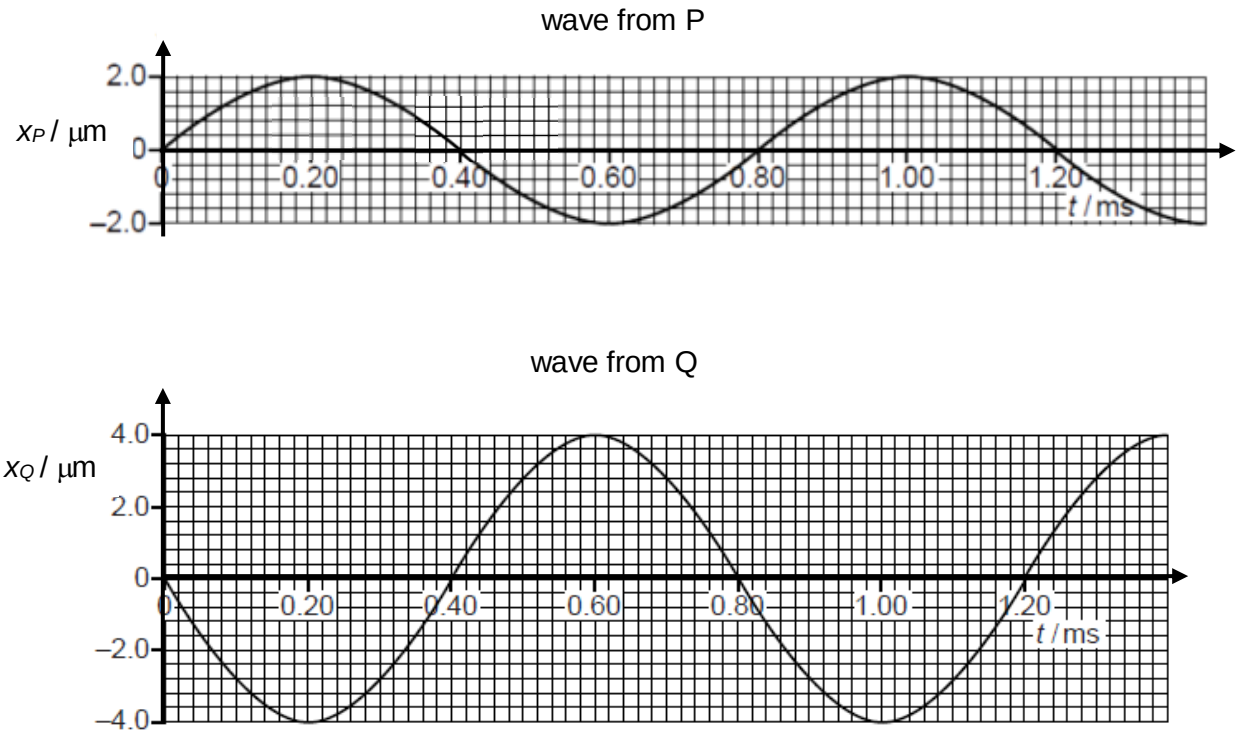


Fig. 3.2

(a) Explain whether the two waves are coherent.

.....

..... [1]

(b) Explain why the sound heard at X is a minimum and is of non-zero intensity.

.....

.....

..... [2]

(c) (i) Using values from Fig. 3.2, calculate the wavelength of the sound waves emitted from the loudspeakers. The speed of sound is 330 m s^{-1}.

wavelength = ... m [2]

(ii) Point O is the position of maximum intensity. The loudspeakers are 0.20 m apart and the distance OX is 2.4 m.

Calculate the distance *D* from the loudspeakers to the line OY. Assume that distance *D* is much greater than the distance between the loudspeakers.

D = ... m [3]

4 **(a)** Fig. 4.1 shows the I – V characteristics of a 6.0 V, 1.5 W filament lamp.

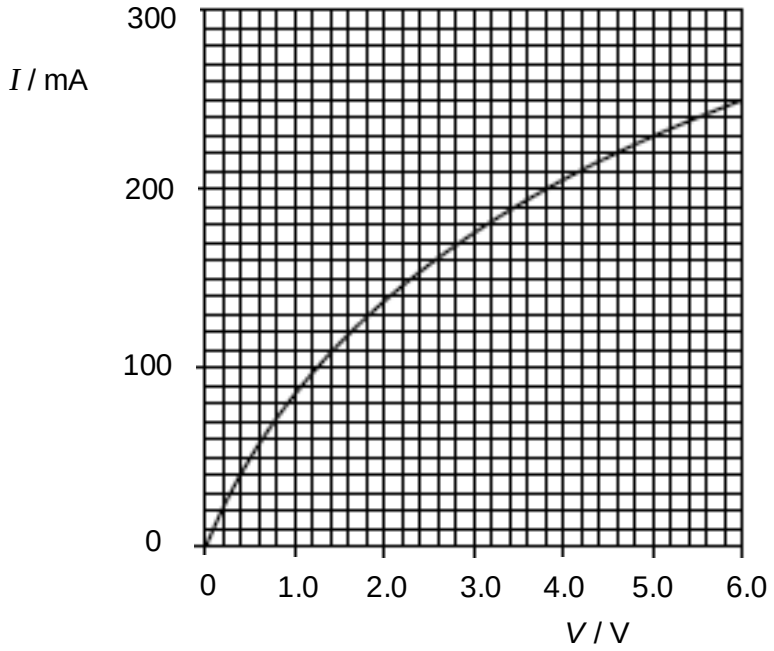


Fig. 4.1

(i) Explain how Fig. 4.1 shows that the resistance of the lamp increases as the potential difference across the lamp increases.

.....

.....

..... [1]

(ii) Using microscopic terms, explain why resistance of filament lamp increases when the potential difference across the lamp increases.

.....

.....

.....

..... [2]

(b) A student designs a circuit for a night light using a 6.0 V, 1.5 W filament lamp and a light dependent resistor (LDR), as shown in Fig. 4.2. The filament lamp is assumed to be ohmic.

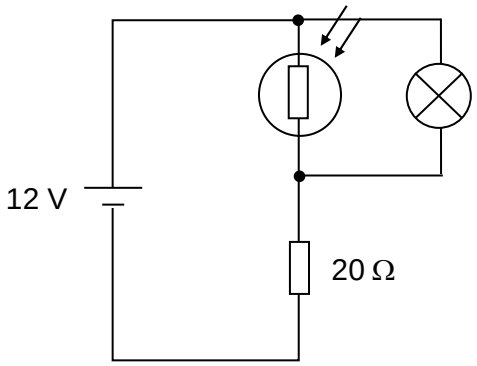


Fig. 4.2

The LDR has a resistance of 10 Ω in daylight and increases to 1000 Ω in the dark.

(i) Using Fig. 4.2, explain why the lamp will not be able to attain normal working conditions in daylight.

.....

.....

.....

..... [2]

(ii) Calculate the resistance of the LDR required in order for the lamp to be under normal working conditions.

resistance = ... Ω [3]

5 An ideal transformer has 3000 turns in its primary coil. It is used to step up a mains supply of root-mean-square current of 20.0 A to a peak current of 4.0 A.

(a) (i) Explain what is meant by the root-mean-square current of 20.0 A.

.....

.....

..... [1]

(ii) Calculate the number of turns of wire on the secondary coil.

number of turns = ... [2]

(b) The secondary coil is connected in series with a resistor of resistance *R*. The variation with time *t* of the current I at the secondary coil is given by the expression

$$I = 4.0 \sin(380t).$$

(i) Determine the frequency of the supply.

frequency = ... Hz [1]

(ii) To prevent overheating, the mean power dissipated in the resistor must not exceed 300 W. Calculate the minimum resistance *R*.

resistance = ... Ω [2]

6 A monochromatic light source has a power output of 0.50 W and a wavelength of 350 nm. The light is incident on a metal surface, which has a work function of 3.8 eV.

(a) Explain quantitatively whether photoelectrons are emitted from the surface.

.....

..... [2]

(b) Calculate the rate of emission of photons from the light source.

rate of emission = ... s^{-1} [2]

(c) Assuming that the radiation is incident normally on an area 4.0×10^{-7} m^2 of the metal surface, calculate the radiation pressure on the surface.

radiation pressure = ... Pa [3]

(d) The intensity of the light is increased. Explain how this will affect your answer in **(a)**.

.....

..... [1]

7 A German astronomer, Johannes Kepler, deduced that for a planet in a circular orbit around the Sun, its period of rotation T and the radius of its orbit r, is related by

$$T^2 \propto r^3 .$$

(a) Using Newton's law of gravitation and considering the mass of Saturn to be M, show that, for a circular orbit of a moon around Saturn,

$$T^2 = \frac{4\pi^2}{GM} r^3 .$$

[2]

(b) Fig. 7.1 contains some of the data for the major moons of Saturn.

moon	period T / 10^6 s	mean distance from centre of Saturn r / 10^9 m	lg (T / s)	lg (r / m)
Enceladus	0.121	0.238	5.08	8.38
Tethys	0.164	0.295	5.21	8.47
Rhea	0.389	0.527		
Titan	1.38	1.22		
Lapetus	6.83	3.56	6.83	9.55

Fig. 7.1

Complete Fig. 7.1 for the moons Rhea and Titan. [2]

(c) Fig. 7.2 shows a graph representing the variation of lg (*T* / s) with lg (*r* / m) for the moons of Saturn, with some of the data from Fig. 7.1 plotted.

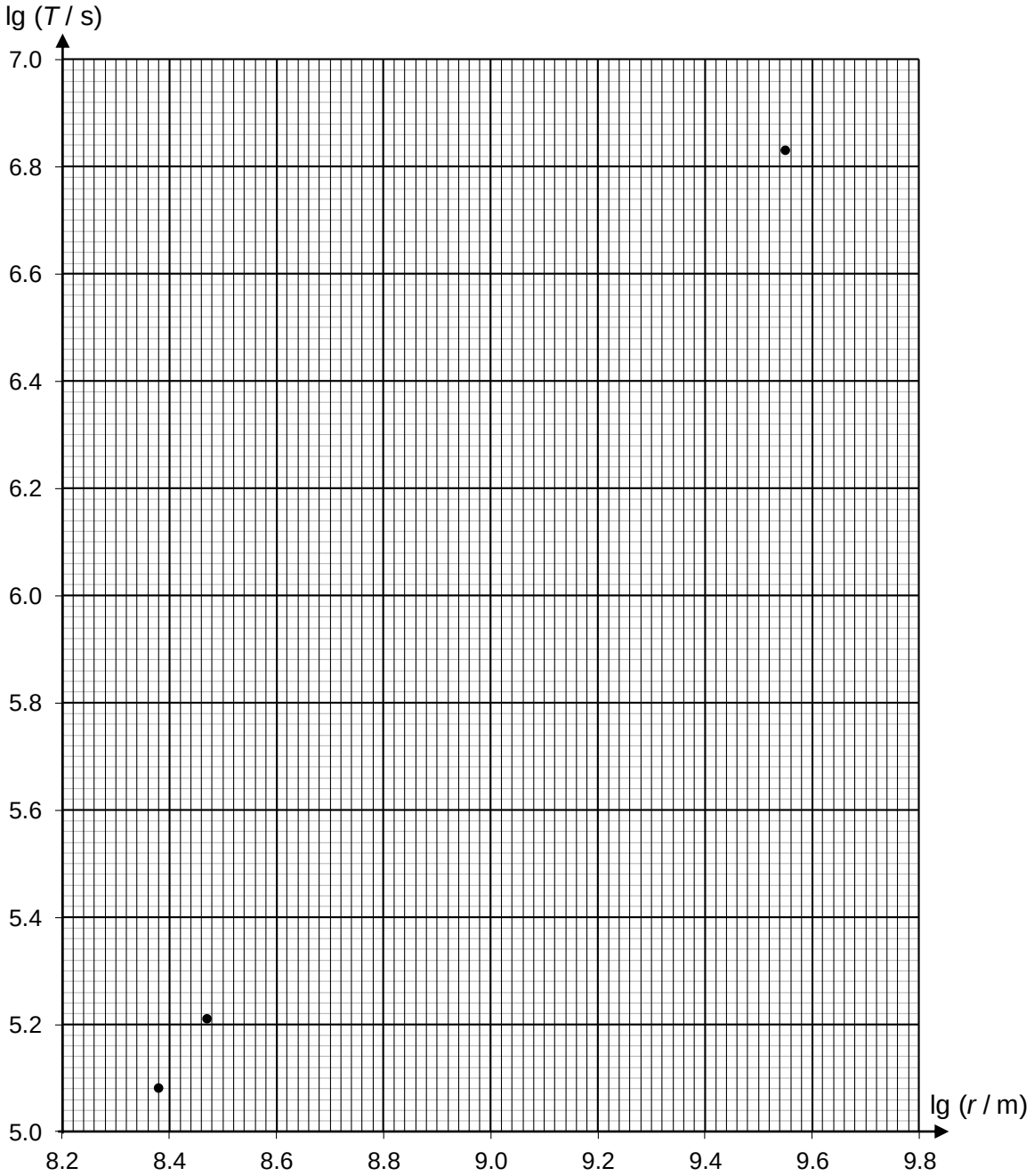


Fig. 7.2

On Fig. 7.2,

(i) plot the points corresponding to the moons Rhea and Titan,

(ii) draw the line of best fit for all the points. [2]

(d) (i) Determine the gradient of the graph in Fig. 7.2.

gradient = ... [2]

(ii) Hence, discuss whether the major moons of Saturn orbit around Saturn in circular orbits.

.....

.....

..... [2]

(e) Dione, which is another moon of Saturn, has an orbital radius of 3.78×10^5 km.

Using the graph in Fig. 7.2, determine the period of Dione's orbit around Saturn.

period = ... s [2]

(f) Scientists were able to determine the mass of planets in the Solar System through studying the orbits of their moons.

(i) Using Fig. 7.2, determine the mass of Saturn.

mass = ... kg [2]

(ii) A student studying the orbits of the moons of Saturn decides to determine the mass of Saturn with the orbital radius and period of Titan only.

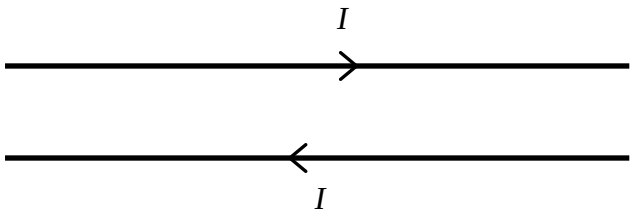
Discuss one disadvantage of using this method as compared to **(f)(i)**.

.....

.....

..... [2]

8 Two equal currents flowing in opposite direction through two long parallel wires experience a magnetic force between them.



The magnetic force on each wire is thought to depend on the current I through the wires. The relation between the magnetic force, F and the current I may be written in the form

$$F = k I^{n}$$

where k and n are constants.

You are provided with a sensitive electronic balance. You may use any of the other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of k and n.

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 to support the two wires while keeping them parallel,

(e) how the magnetic force would be determined,

(f) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

…… [12]

End of paper

Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9646/03**
Higher 2

Paper 3 Longer Structured Questions

19 September 2016

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 **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		/	7
4		/	8
5		/	7
6		/	20
7		/	20
8		/	20
Total		/	80

This document consists of **24** printed pages.

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}

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,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{{x_0}^2 - x^2}$
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,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** questions in this Section.

1 A ship of mass 2.4×10^4 kg is moving with a speed of 11.0 m s^{-1} when the captain noticed an iceberg directly ahead. The iceberg is at a distance of 500 m away and is drifting directly towards the ship with a speed of 1.0 m s^{-1}. In order to avoid colliding with the iceberg, the captain ordered the engines into full reverse. The ship is just able to stop 1.0 m from the iceberg.

(a) Determine the magnitude of the constant retarding force exerted by the ship's engines. Ignore the effect of viscous drag force.

force = ... N [4]

(b) If the ship's captain had not noticed the iceberg, the ship will continue moving with a speed of 11.0 m s^{-1} and collide with it. After collision, both the ship and iceberg will move off together with a speed of 0.80 m s^{-1} in the original direction of travel of the iceberg.

(i) Determine the mass of the iceberg.

mass = ... kg [2]

(ii) Assuming that the duration of collision is 1.5 s, determine the magnitude of the average force exerted on the iceberg by the ship.

force = ... N [2]

2 Fig. 2.1 shows the variation with distance x of the gravitational potential ϕ between the surface of the Earth and the surface of the Moon. At point P, the gravitational potential is a maximum.

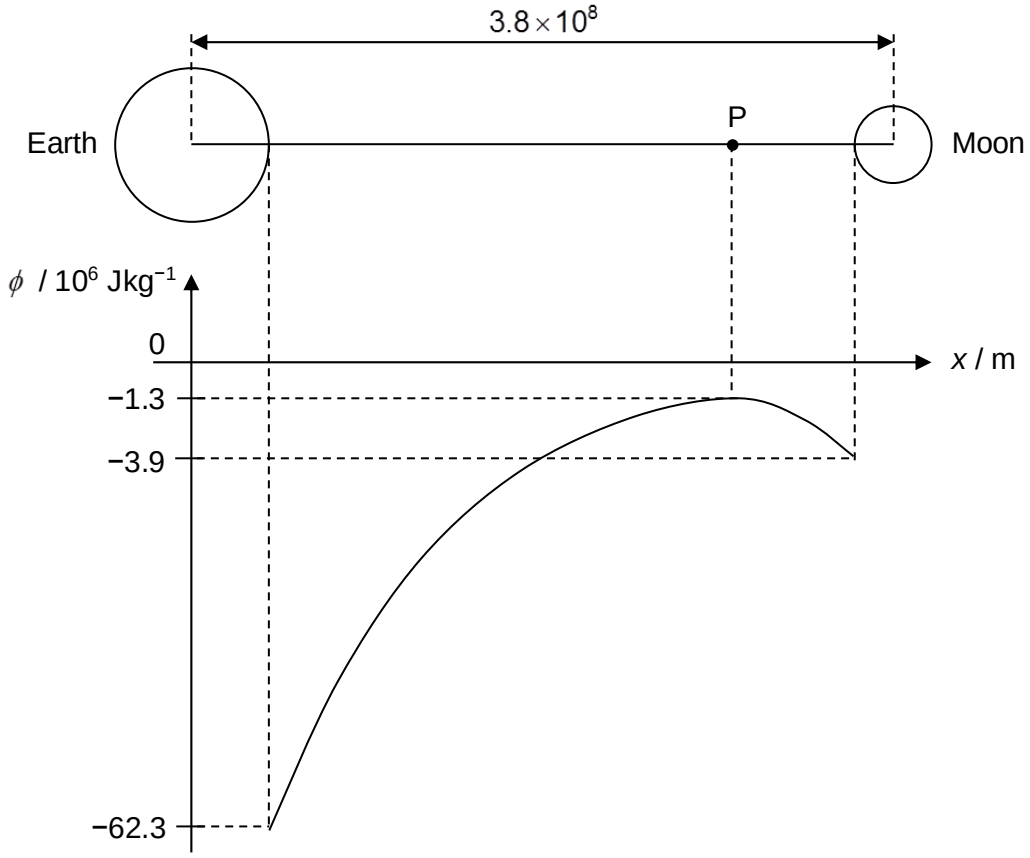


Fig. 2.1

The centres of both masses are separated by a distance of 3.8×10^{8} m. The masses of the Earth and the Moon are 6.0×10^{24} kg and 7.4×10^{22} kg respectively.

(a) Explain

(i) what is meant by the term *gravitational potential*,

.....

.....

..... [1]

(ii) why the values of the potential shown in Fig. 2.1 are all negative.

.....

.....

..... [2]

(b) (i) State how the resultant gravitational field strength at any point between the Earth and the Moon can be deduced from the graph in Fig. 2.1.

.....

..... [1]

(ii) Determine the distance from the centre of the Earth where the resultant gravitational field strength is zero.

distance = ... m [2]

(iii) On Fig. 2.2, sketch a graph to show the variation of the resultant gravitational field strength with distance *x* between the surface of the Earth and the surface of the Moon. Numerical values are not required.

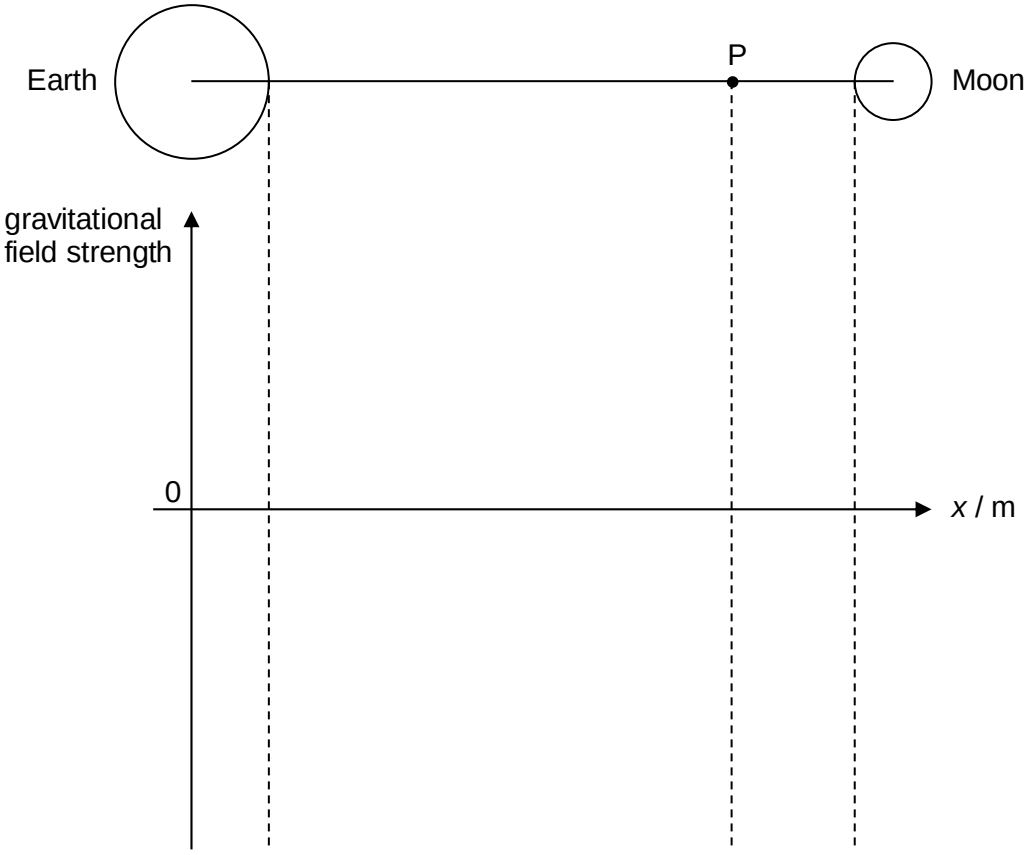


Fig. 2.2

[1]

(c) A spacecraft is to be launched from the surface of the Earth and is to reach the surface of the Moon.

Determine the minimum speed required to project the spacecraft from the surface of the Earth. Explain your answers clearly.

minimum speed = ... ms^{-1} [3]

3 An electron passes through a hole in an earthed plate P_1 with speed 4.0×10^6 ms^{-1} and emerges from plate P_2, which is at potential +200 V, as shown in Fig. 3.1. It then enters a region of uniform radial electric field, provided by two metallic half-cylinders, and moves at a constant speed in a semi-circular path of radius *r* from slits S_1 to S_2.

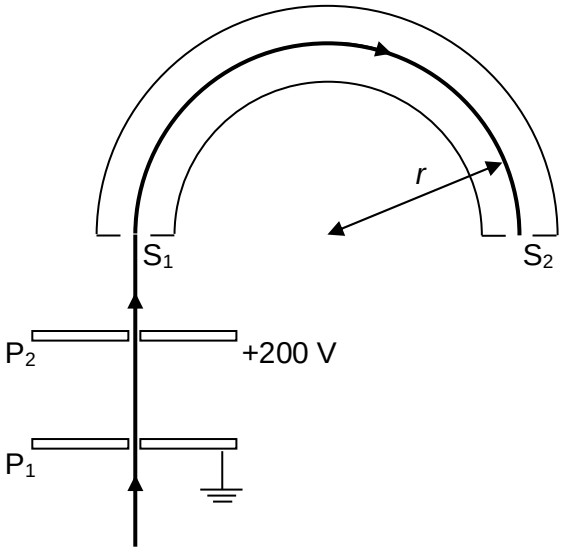


Fig. 3.1

(a) Calculate the speed of the electron as it leaves P_2.

speed = ... ms^{-1} [2]

(b) (i) Explain why the electron moves in a semi-circular path from S_1 to S_2 at a constant speed.

.....

.....

.....

..... [2]

(ii) On Fig. 3.1, draw five lines to represent the electric field inside the half-cylinders. [1]

(iii) Determine the radius r of the semi-circular path, given that the electric field strength along the path of the electron is 2.0×10^3 Vm^{-1}.

r = ... m [2]

4 **(a)** Fig. 4.1 shows a rectangular copper loop PQRS with the side RS inside a solenoid. The plane of the rectangular loop is along the axis of the solenoid. The rectangular loop is pivoted on two knife-edges X and Y. X and Y are always at the same distance from P and Q respectively. A rider of mass 3.0 g is placed on the side PQ. Electrical connections are made through the knife-edges such that the same current flows through both the solenoid and the loop.

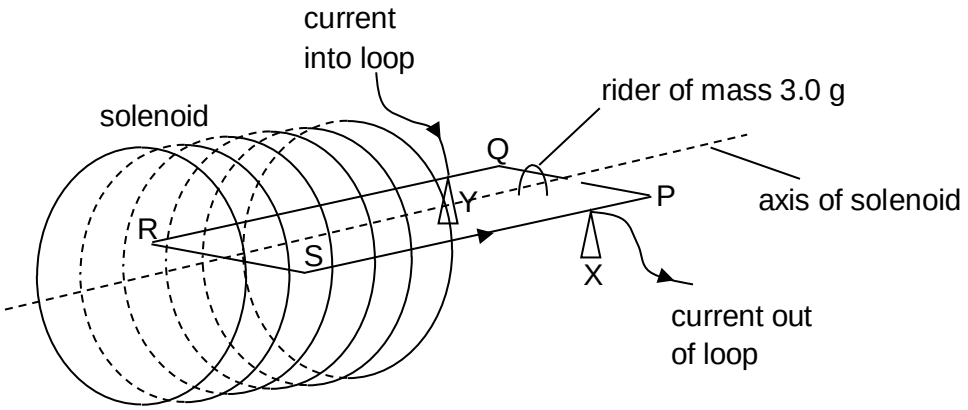


Fig. 4.1

The magnetic flux density of the solenoid is directly proportional to the current through the solenoid, and the flux density is assumed to be constant within the solenoid but decreases to zero outside the solenoid.

(i) On Fig. 4.1, indicate the flow of the current through the solenoid. Label the current I. [1]

(ii) When a current of I_1 is passed through the loop, in order to balance the loop horizontally, the knife edges X and Y are positioned such that XP = $\frac{1}{4}$PS and YQ = $\frac{1}{4}$QR . When a current of I_2 is passed through the loop, X and Y need to be shifted such that XP = $\frac{1}{2}$PS and YQ = $\frac{1}{2}$QR in order to regain its balance.

Determine the ratio of $\frac{I_1}{I_2}$.

ratio = ... [3]

(b) Fig. 4.2 shows a rectangular coil placed at the centre of the solenoid with its plane perpendicular to the axis of the solenoid.

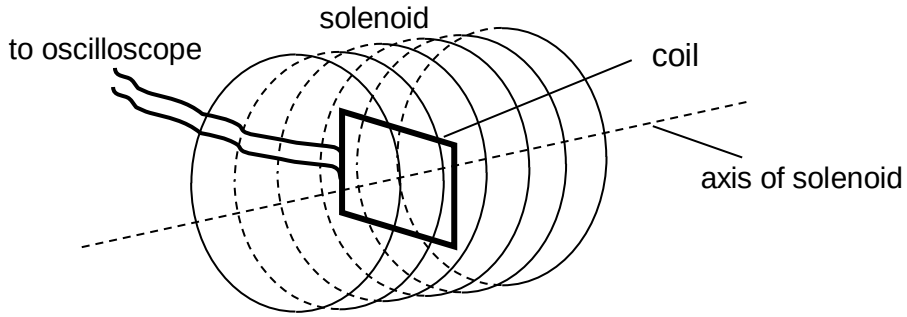


Fig. 4.2

The solenoid has 400 turns, a cross-sectional area of 0.0050 m^2 and a length of 50 cm. An alternating current of 50 Hz is passed through the solenoid. The rectangular coil has nine turns with dimensions of 0.010 m by 0.018 m. The ends of the coil are connected to a cathode ray oscilloscope.

Fig. 4.3 shows the variation with time of the current through the solenoid.

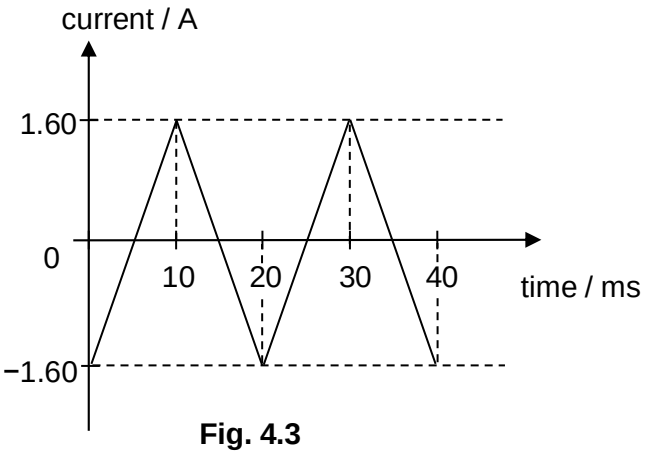


Fig. 4.3

(i) The flux density of the solenoid is given by $B = \mu_o nI$, where μ_o is the permeability of free space, n is the number of turns per unit length of the solenoid and I is the current through the solenoid.

Calculate the magnitude of the e.m.f. induced in the coil.

e.m.f. = ... V [2]

(ii) On Fig. 4.4, sketch a labelled graph to show the variation with time of the induced e.m.f. in the coil over two cycles of current change.

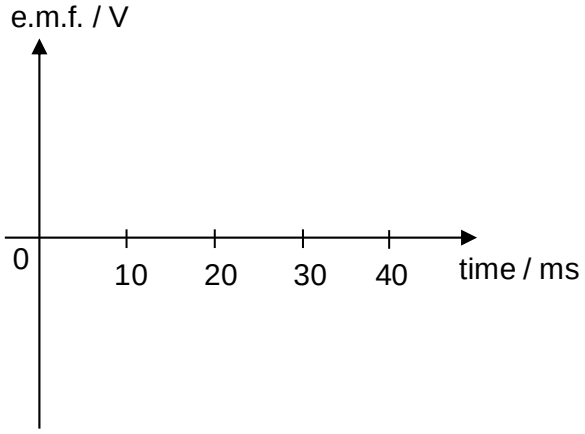


Fig. 4.4

[2]

5 (a) (i) Explain the importance of the existence of the metastable state in an atom that helps in the production of laser.

.....

.....

.....

.....

..... [3]

(ii) A semiconductor laser emits pulses of light of wavelength 680 nm. Each pulse is 30 ms long. If the average output power of a pulse is 6.0 W, calculate the number of photons in each pulse.

number of photons =..... [2]

(b) A junction is formed between slices of p-type and n-type semiconductor materials when they are placed together.

Describe the origin of the depletion region at the junction.

.....

.....

.....

.....

..... [2]

Section B

Answer **two** questions in this Section.

6 **(a)** State what is meant by *simple harmonic motion*.

.....

.....

..... [2]

(b) A light helical spring that has an unstretched length of 0.300 m is placed vertically on a flat surface. A block of mass 0.500 kg is placed on the spring and gently lowered vertically until equilibrium is reached. The spring has then been compressed elastically by a distance of 0.050 m.

Calculate, for the compression of the spring,

(i) the spring constant of the spring,

spring constant = ... N m^{-1} [2]

(ii) the loss in gravitational potential energy of the block,

loss = ... J [1]

(iii) the elastic potential energy gained by the spring.

gain = ... J [1]

(c) The block is then set into simple harmonic motion of amplitude 0.050 m.

(i) Calculate the force exerted on the block by the spring when the block is at

1. the lowest point of its motion,

force = ... N [1]

2. the highest point of its motion.

force = ... N [1]

(ii) Using your answer in **(c)(i)**, calculate the angular frequency of the oscillation.

angular frequency = ... rad s^{-1} [2]

(iii) Hence, determine

1. the maximum speed of the block,

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

2. the maximum kinetic energy of the block.

maximum kinetic energy = ... J [1]

(d) Fig. 6.1 is a table of energies of the simple harmonic motion. Complete the table.

	gravitational potential energy / J	elastic potential energy / J	kinetic energy / J	total energy / J
lowest point	0			
equilibrium position				
highest point				

Fig. 6.1

[5]

(e) On the axes of Fig. 6.2 below, sketch four graphs to show the variation with position of the four energies in Fig. 6.1. Label each graph clearly.

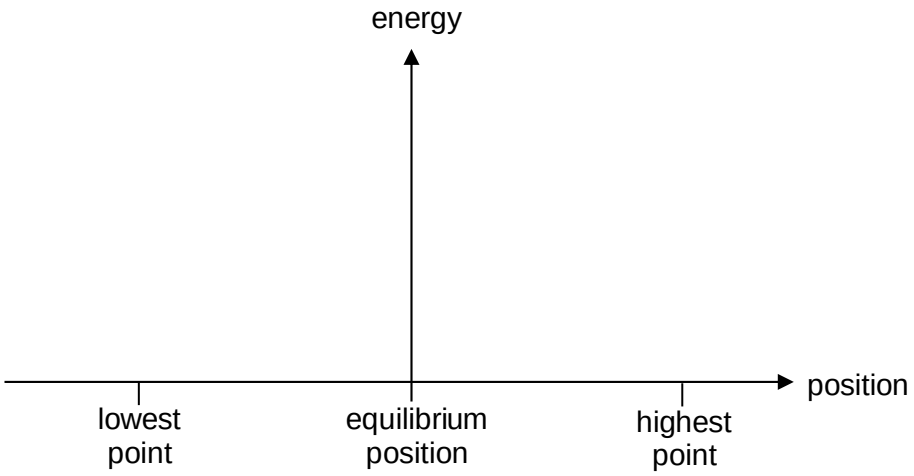


Fig. 6.2

[3]

7 (a) (i) Explain what is meant by an *ideal gas*.

.....

..... [1]

(ii) List all the quantities that determine the state of an ideal gas.

.....

..... [2]

(b) A thermally insulated container is divided into two sections by a thermally insulating and frictionless partition. The partition is initially held in place as shown in Fig. 7.1. X contains an ideal gas of volume 2.00×10^{-3} m^3 and pressure 5.0×10^7 Pa at a temperature of 177 °C. Y contains the same gas of volume 4.50×10^{-3} m^3 and pressure 1.5×10^7 Pa at a temperature of 27 °C.

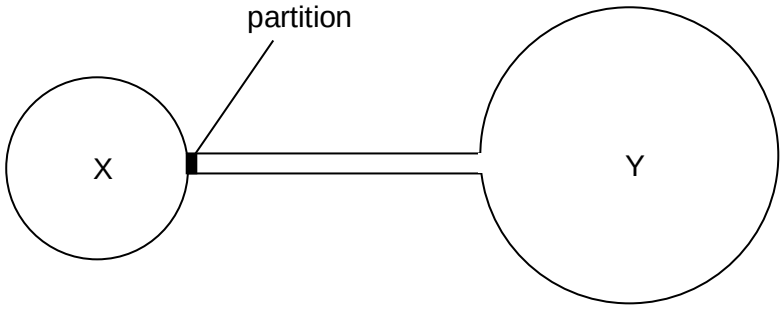


Fig. 7.1

(i) Calculate the amount of gas, in moles, in X and Y separately.

amount of gas in X = ... mol [1]

amount of gas in Y = ... mol [1]

(ii) The partition is moved towards the right. Using the first law of thermodynamics, state and explain how the temperature of the gas in X changes.

.....

.....

..... [2]

(iii) The partition is removed allowing gas in X and Y to mix. Calculate the final temperature of the gas in the container given that the final pressure of the gas is 3.0×10^7 Pa.

temperature = ... K [3]

(iv) The gas leaks slowly from the container such that after a time of 35 days, the pressure reduces by 3.0 %. The temperature remains constant.

1. Determine the number of gas atoms that remains in the container.

number of gas atoms = ... [2]

2. Calculate the average numbers of gas atoms that leaks from the container per unit time.

average rate of escape = ... s^{-1} [2]

3. Explain why the rate of escape obtained in **(b)(iv)2.** is an average rate.

.....

.....

..... [1]

(c) Fig. 7.2 below shows the variation with volume of the pressure of a new sample of an ideal gas in the cylinder. The gas is initially at state W.

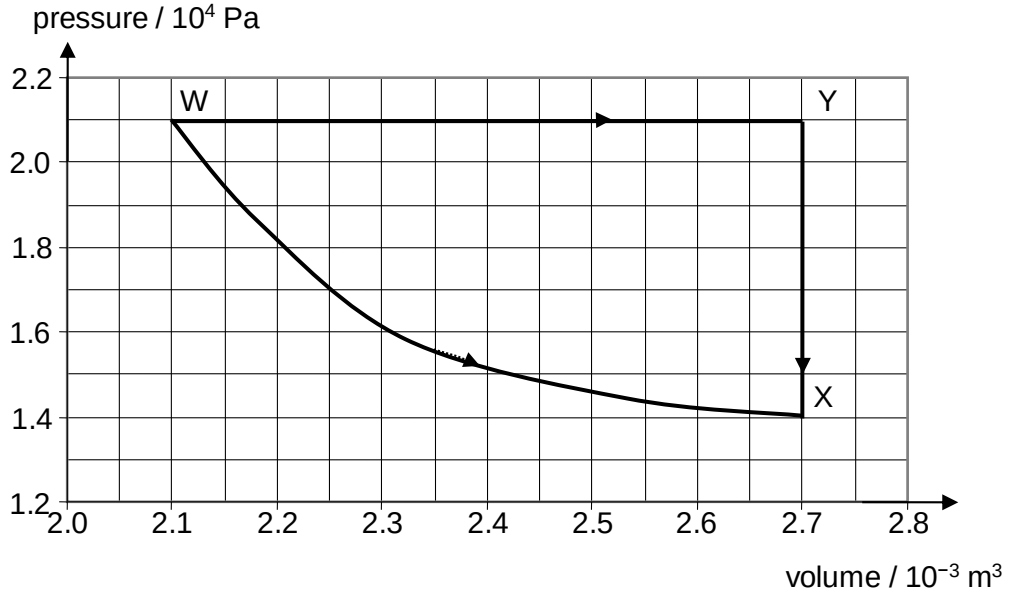


Fig. 7.2

When the gas is expanded from W → X along the curved path, 20.5 J of heat is supplied to the gas and 15.6 J of work is done by the gas.

Using Fig. 7.2, determine

(i) whether the process W → X is isothermal,

.....

..... [2]

(ii) the quantity of heat supplied to the gas during the change W → Y → X.

heat supplied = ... J [3]

8 **(a)** Uranium-235 nuclei when bombarded by neutrons may undergo nuclear reactions. One such reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$$

The binding energy per nucleon of both barium-144 and krypton-90 is approximately 8.5 MeV. The minimum energy released for this reaction is 227 MeV.

(i) What is the role of the neutrons that were emitted?

..... [1]

(ii) Determine the binding energy per nucleon of uranium-235.

binding energy per nucleon = ... MeV [3]

(iii) Using the concept of nuclear binding energy, explain quantitatively why energy is released in this reaction.

.....

.....

.....

.....

.....

..... [3]

(iv) A nuclear power station uses uranium-235 as fuel and has an output power of 10^7 W. The overall efficiency of the station is 10%. Determine the amount of uranium-235 consumed in one hour.

amount consumed = ... g [3]

(b) The isotope uranium-235 in **(a)** is formed from the decay of plutonium-239 by α-emission. The average half-life of plutonium-239 is 2.4×10^4 years.

(i) Write down a nuclear equation for the nuclear reaction, given that the chemical symbol for plutonium is *Pu*.

..... [1]

(ii) Suggest why the half-life is an average value.

.....

..... [1]

(iii) Given that plutonium-239 is stationary before the decay, determine the ratio

$$\frac{\text{intitial kinetic energy of } \alpha\text{-particle}}{\text{initial kinetic energy of uranium-235}}.$$

ratio = ... [3]

(iv) In a sample of radioactive material, the ratio of plutonium atoms to uranium atoms is 1:5.

1. Estimate the age of the sample, assuming that originally there is no uranium present.

age = ... years [2]

2. State two other assumptions that are made in the calculations.

.....

.....

..... [2]

(v) Fig. 8.1 shows the decay graph of plutonium-239, where N_o and $t_{\frac{1}{2}}$ represents the initial number of atoms and the half-life of plutonium-239 respectively. On Fig. 8.1, sketch a graph to show the growth curve of uranium-235, labelling the values on the axes clearly.

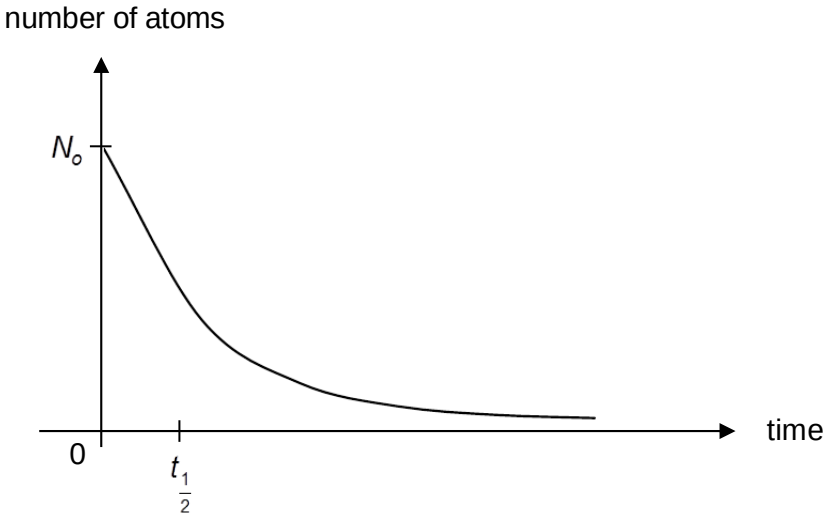


Fig. 8.1

[1]

End of paper

Answers to JC2 Preliminary Examination Paper 1 (H2 Physics)

1	**B**	**9**	**B**	**17**	**A**	**25**	**B**	**33**	**C**
2	**B**	**10**	**B**	**18**	**D**	**26**	**C**	**34**	**B**
3	**A**	**11**	**C**	**19**	**B**	**27**	**D**	**35**	**A**
4	**D**	**12**	**D**	**20**	**B**	**28**	**D**	**36**	**D**
5	**C**	**13**	**D**	**21**	**C**	**29**	**C**	**37**	**C**
6	**C**	**14**	**A**	**22**	**C**	**30**	**A**	**38**	**C**
7	**C**	**15**	**B**	**23**	**C**	**31**	**D**	**39**	**B**
8	**A**	**16**	**D**	**24**	**D**	**32**	**C**	**40**	**C**

Suggested Solutions:

1 $\frac{a^2}{P}$ has no units.

units of $P = \text{m}^2$

QT^2 has units of m.

units of $Q = \text{m s}^{-2}$

Answer: B

2 Taking downwards as positive,

$s_y = u_y t + \frac{1}{2}(a_y)(t)^2$

$500 = (208\sin 20°)t + \frac{1}{2}(9.81)(t)^2$

$t = 5.2 \text{ s}$

Horizontally,

$s_x = u_x t$

$= (208\cos 20°)5.2$

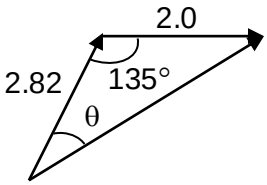
$= 1016 \text{ m}$

Answer: B

3 The acceleration at maximum height is equal to the acceleration of free fall. This is because at maximum height, speed is zero and thus there is no air resistance and the only force acting on the ball is its weight.

Answer: A

4 Impulse = $F\Delta t = (0.2)(10) = 2.0$ Ns in the easterly direction.



$F\Delta t = \Delta p = m\Delta v = 2.0$

$\overrightarrow{\Delta p} = \overrightarrow{p_f} - \overrightarrow{p_i} = \overrightarrow{2.0} \Rightarrow \overrightarrow{p_f} = \overrightarrow{p_i} + \overrightarrow{2.0}$

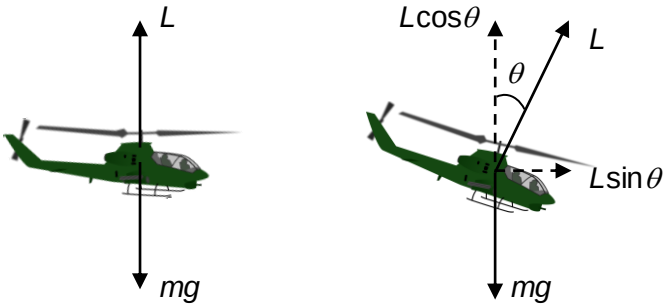
Using cosine rule,

$\overrightarrow{p_f} = 4.46$ Ns $\Rightarrow v_f = 2.23$ m s^{-1}

$\theta = 18.5°$

Answer: D

5



Initially, for vertical motion,

$50 = 0 + \frac{1}{2}a(4.0)^2$

$\therefore a = 6.25$ m s^{-2}

Consider forces acting on helicopter,

$L - mg = ma = m(6.25)$

$\therefore L = 16060$ N

With the blades tilted at an angle $52°$ to the vertical,

horizontally, $L\sin 52° = m(a_1) \Rightarrow a_1 = 12.7$ m s^{-2}

Answer: C

6 $k_1 = \frac{60}{0.06} = 1000$ N m^{-1}

$k_2 = \frac{80 - 60}{0.14 - 0.06} = 250$ N m^{-1}

The work done on the sample is the area under the graph, thus, letting x be the extension,

$\frac{1}{2}(1000)(0.06)^2 + 60(x - 0.06) + \frac{1}{2}(250)(x - 0.06)^2 = 4.4$

$x = 0.10$ m $= 10$ cm

Answer: C

7 Perpendicular distance between R and PQ $= \frac{5.0}{2}\tan 60° = 4.33$ cm

Let the normal contact force acting on the rod by the wall be N_{rod}.
Taking moments about P,
$(0.100)(9.81)(2.5\text{ cm}) + (3.0)(5.0\text{ cm}) = N_{rod}(4.33\text{ cm})$
$N_{rod} = 4.0$ N

Answer: C

8 The forces acting on the cardboard consist of two couples. Thus the forces cancel out with one another and there is no net force, which means that the cardboard is in translational equilibrium.

The perpendicular distance between the clockwise couple is larger than that between the anticlockwise couple, thus there will be a net torque clockwise.

$$\sum \tau = 1.0(5.0\times10^{-2}) - (1.0)\left(5.0\times10^{-2}\cos 45°\right) = 1.5\times10^{-2}\text{ N m}$$

Answer: A

9 $$P_{out} = \frac{W}{t} = \frac{Fd}{t} = \frac{mgd}{t} = \frac{400\times9.81\times1200}{2.0\times60} = 39240\text{ W}$$

$$\varepsilon = \frac{P_{out}}{P_{in}} = 0.80$$

$$P_{in} = \frac{39240}{0.80} = 49050\text{ W}$$

$$P_{wasted} = P_{in} - P_{out} = 49050 - 39240 = 9810\text{ W}$$

Answer: B

10 On the inclined plane,

$$v^2 = u^2 + 2as$$
$$= 2.5^2 + 2(-9.81\sin 30°)(0.50)$$
$$= 1.345$$
$$v = 1.160\text{ m s}^{-1}$$

Minimum KE occurs at top of parabolic path, where velocity is $v\cos 30° = 1.00\text{ m s}^{-1}$.
$\therefore KE_{\text{min}} = 0.5\times0.200\times1.00^2 = 0.10$ J

Answer: B

11 The horizontal component of tension provides the centripetal force necessary for a seat to move in circular motion.

Resolving and equating forces in the horizontal direction, $T\sin\theta = ma_c$

$T\sin\theta = \dfrac{mv^2}{r}$ ----- (1)

Resolving and equating forces in the vertical direction, $T\cos\theta = mg$ ----- (2)

Solving, we have

$\tan\theta = \dfrac{v^2}{rg}$

$\tan 30.0° = \dfrac{v^2}{(3.50\sin 30.0° + 3.00)\times 9.81}$

$v = 5.19\ \text{m s}^{-1}$

Answer: C

12 At the top of the circle,

$N + W = \dfrac{mv_{top}{}^2}{r}$

For the ride to be safe, $N > 0$. Therefore, $v_{top} > \sqrt{rg}$.

By conservation of energy,
loss in K.E. = gain in G.P.E.

$\dfrac{1}{2}mv_{bottoom}{}^2 - \dfrac{1}{2}mv_{top}{}^2 = mg(2r)$

$v_{bottom} > \sqrt{5rg}$

Answer: D

13 Let the distance of the particle from M_1 be *d*.

$\dfrac{GM_1m}{d^2} = \dfrac{GM_2m}{(r-d)^2}$

$\dfrac{M_1}{M_2} = \dfrac{d^2}{(r-d)^2}$

$\dfrac{\sqrt{M_1}}{\sqrt{M_2}} = \dfrac{d}{r-d}$

$r\sqrt{M_1} = d\left(\sqrt{M_1} + \sqrt{M_2}\right)$

$d = r\left(\dfrac{\sqrt{M_1}}{\sqrt{M_1} + \sqrt{M_2}}\right)$

Answer: D

14 By Newton's second law of motion,

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v^2 = \frac{GM}{r}$$

Since $-\frac{GM}{r} = -30 \times 10^6$, $v^2 = 30 \times 10^6$.

For the rocket in the new orbit, $v_{new}{}^2 = 10 \times 10^6$.

Solving, we have $v_{new} = \frac{v}{\sqrt{3}}$.

Answer: A

15 Total energy $E = \frac{1}{2} m\omega^2 A^2$

$$E_K = \frac{1}{2} m\omega^2 \left(A^2 - x^2\right)$$

$$\frac{3}{4} E = \frac{1}{2} m\omega^2 \left(A^2 - x^2\right)$$

$$\frac{3}{4}\left(\frac{1}{2} m\omega^2 A^2\right) = \frac{1}{2} m\omega^2 \left(A^2 - x^2\right)$$

$$x = \frac{A}{2}$$

Answer: B

16 Light damping caused amplitude and energy of the oscillating system to decrease, but the frequency may decrease slightly or remain unchanged.

Answer: D

17 Heat loss by water = Heat gain by ice

$m_{water} c \Delta\theta_1 = m_{ice} l_f + m_{ice} c \Delta\theta_2$

$c(80 - T) = l_f + c(T - 0)$

$c(80 - 2T) = l_f$

$(4.2 \times 10^3)(80 - 2T) = 3.3 \times 10^5$

$80 - 2T = 78.6$

$T = 0.71\,°\text{C}$

Answer: A

18 $pV = nRT$

$n = \dfrac{pV}{RT}$

$\dfrac{n_x}{n_y} = \dfrac{4V/3T}{V/T} = 4:3$

Answer: D

19 Use the initial conditions provided to calculate the amount of air needed.

$pV = nRT$

$n = \dfrac{pV}{RT}$

$n_{initial} = \dfrac{(250\times10^3)(2\times10^{-4})}{(8.31)(300)} = 0.02$

$n_{final} = \dfrac{(350\times10^3)(2\times10^{-4})}{(8.31)(300)} = 0.028$

$\Delta n = 0.028 - 0.020 = 0.008$

Answer: B

20 $T = 4$ ms

$f = \dfrac{1}{T} = \dfrac{1}{4\times10^{-3}} = 250$ Hz

$\lambda = \dfrac{v}{f} = \dfrac{320}{250} = 1.28$ m

Answer: B

21 Answer: C

22 For any charge q, the electric force that it experiences is $F_E \propto \dfrac{Qq}{r^2}$. Since the charge experiences no resultant electric force, the forces due to $-4Q$ and $+Q$ must be zero. This could be possible if the charge is at positions C or D.

Since $\dfrac{4Qq}{(x+3)^2} = \dfrac{Qq}{x^2}$, where x is the distance from $+Q$, we have $x = 3$.

Answer: C

23 Resolving the initial velocity into its vertical component, we have $u_y = v\cos\theta$.

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

$eV = \dfrac{1}{2}m_e(v\cos\theta)^2$.

Answer: C

24 Energy supply $= IVt$
$= (50)(12)(3600)$
$= 2.2$ MJ

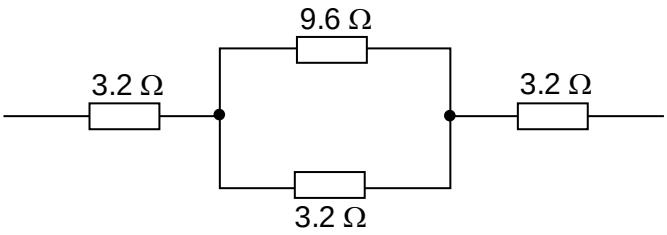
Answer: D

25 $I = \dfrac{Q}{t} = \dfrac{6.0}{120} = 0.050$ A

$V = E - Ir$
$\dfrac{W}{Q} = E - Ir$
$\dfrac{48}{6.0} = 9.0 - (0.050)r$
$r = 20\ \Omega$

Answer: B

26



$R_{\text{equivalent}} = 3.2 + \left(\dfrac{9.6 \times 3.2}{9.6 + 3.2}\right) + 3.2 = 8.8\ \Omega$

Answer: C

27 The resultant force on C due to the currents in A and E will point towards West. Similarly, the resultant force on C due to the currents in B and D points towards West as well. While the force on C due to the current in F points East, its magnitude is the smallest. Hence, the resultant force on C due to all the five currents is towards West.

Answer: D

28 The magnetic field generated between the two arms of the iron core points up. The current in the conductor points inwards. By Fleming's left hand rule, the force on the conductor points towards the right.

Answer: D

29 acceleration of the rod $a = \dfrac{BIx}{m}$

Answer: C

30 The magnetic flux linkage through the coil remains constant as long as it moves parallel to the conductor. Hence, no electromagnetic induction occurs in the coil.

Answer: A

31 $I_{r.m.s.} = \frac{5}{2} = 2.5$ A

$P_{r.m.s.} = 2.5^2 \times 5 = 31.25$ W

Answer: D

32 Answer: C

33 $hf = \phi + eV_s$ ----- (1)

$h\frac{f}{2} = \phi + eV_s'$ -----(2)

(1) – (2):

$h\frac{f}{2} = eV_s - eV_s'$

$\phi + eV_s' = eV_s - eV_s'$

$2eV_s' = eV_s - \phi$

$V_s' = \frac{V_s}{2} - \frac{\phi}{2e}$

Therefore, $V_s' < \frac{V_s}{2}$.

Answer: C

34 Option A is wrong. The longest wavelength λ_2 corresponds to the smallest energy.

Option B is correct. $\frac{hc}{\lambda_2} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_3}$ and so $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} - \frac{1}{\lambda_3}$.

Option C is wrong. A photon of the shortest wavelength λ_1 is emitted and has the largest associated momentum. An electron is not emitted due to the transition.

Option D is wrong. The transitions give rise to an emission spectrum where bright lines are observed on a dark background.

Answer: B

35 Since $T = e^{-2kd}$, we have

$T = e^{-2k(2.0\times10^{-10})}$

When the barrier width is reduced, we have

$T' = e^{-2k(0.8\times10^{-10})}$

$T' = e^{-2k(2.0\times10^{-10})(0.4)}$

$T' = T^{0.4}$

Answer: A

36 The photons emitted through stimulated emission possess similar energy, frequency, direction of polarisation. Using de broglie's relation, the momentum should be the same as well since the wavelength is the same.

Answer: D

37 The 2 stage laser has the least efficiency because there is an equal chance for stimulated absorption and stimulated emission.

Answer: C

38 The majority charge carriers for p-type semiconductors are holes and therefore the minority charge carriers are electrons.

Answer: C

39 Since the final nuclide is an isotope of the initial nuclide, both nuclides have the same proton number. By considering the combination of decay which results in no change in proton number, the only possible answer is B.

Answer: B

40 At $t = 0$,

$A_{ox} + A_{oY} = 352 - 16 = 336 \text{ min}^{-1}$

Since $A_{oY} = 256 - 16 = 240 \text{ min}^{-1}$, $A_{ox} = 96 \text{ min}^{-1}$.

After 12 days, sample X and Y would have undergone 3 half-lives and 4 half-lives respectively.

$A_X = 96 \times \left(\frac{1}{2}\right)^3 = 12 \text{ min}^{-1}$

$A_Y = 240 \times \left(\frac{1}{2}\right)^4 = 15 \text{ min}^{-1}$

Therefore, the total count rate is 12 + 15 + 16 = 43 min^{-1}.

Answer: C

Answers to JC2 Preliminary Examination Paper 2 (H2 Physics)

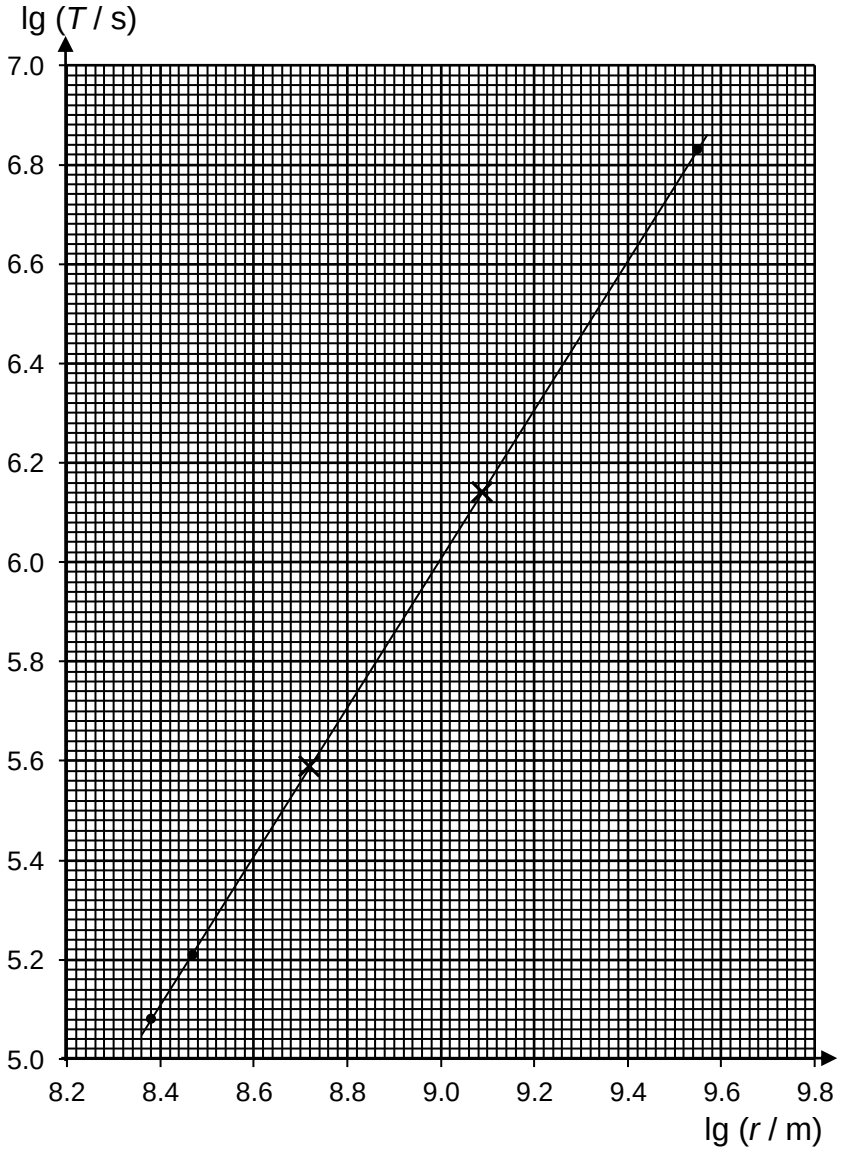
Suggested Solutions:

No.	Solutions	Remarks
1(a)(i)	A dimensionless constant is a constant <u>without any units</u> whose presence in the equation makes the equation numerically correct.	[1] for correct answer
1(a)(ii)	Units of $v = m\ s^{-1}$ Units of $\left[\frac{kI}{NAQ}\right] = (\text{Units of } k)\frac{C\ s^{-1}}{m^{-3}\ m^2\ C}$ $= (\text{Units of } k)\, m\ s^{-1}$ For the equation to be homogeneous, k is dimensionless.	[2] for correct answer
1(b)	$W = \frac{\pi p r^4}{8L\left(\frac{V}{t}\right)}$ $\frac{\Delta W}{W} = 4\left(\frac{\Delta r}{r}\right) + \left(\frac{\Delta p}{p}\right) + \left(\frac{\Delta L}{L}\right) + \left(\frac{\Delta \frac{V}{t}}{\frac{V}{t}}\right)$ $= 4(0.05) + (0.02) + (0.005) + (0.03) = 0.255$ $\Delta W = 0.3 \times 10^{-3}$ kg m^{-1} s^{-1} $W = (1.1 \pm 0.3) \times 10^{-3}$ kg m^{-1} s^{-1}	[1] fractional uncertainty formula of W [1] for ΔW [1] answer
2(a)	It is a <u>net upward force</u> acting on a body by a fluid when it is immersed in the fluid. It is due to the <u>difference in pressure</u> at the <u>top and bottom</u> of the immersed portion of the body,	[1] [1]
2(b)(i)	work done on object = upthrust $\times$ displacement $= (1000)(50 \times 10^{-6})(9.81)(0.10)$ $= 0.04905$ $= 0.049$ J	[1] for correct substitution [1] for correct answer
2(b)(ii)	By conservation of energy, Gain in GPE + Gain in KE = Work done by water on object $(mgh - 0) + (\frac{1}{2}mv^2 - 0) = 0.04905$ $(850)(50 \times 10^{-6})(9.81)(0.10) + \frac{1}{2}(850)(50 \times 10^{-6})v^2 = 0.04905$ $v^2 = 0.346$ $v = 0.59$ m s^{-1}	[1] for correct substitution [1] for correct answer

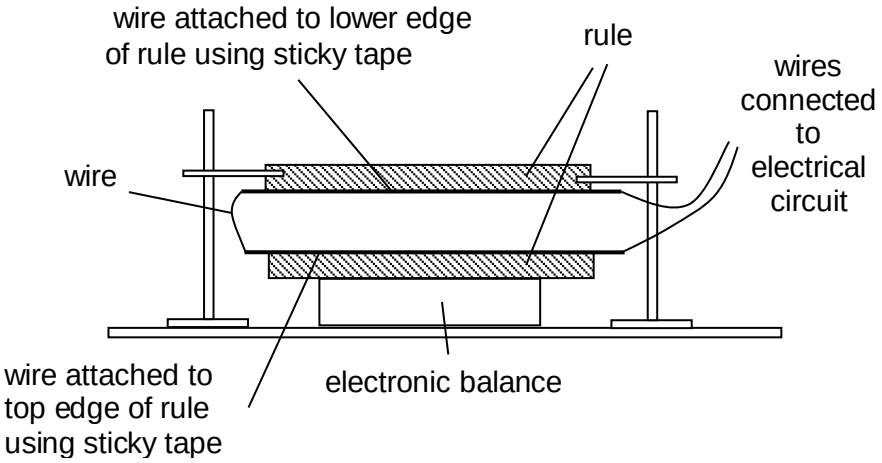
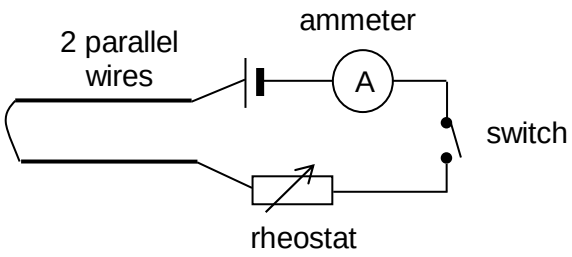
2(b)(iii)	In practice, the object loses energy as it moves up, since it is doing work against drag forces. This means that the gain in kinetic energy is smaller, since the gain in gravitational potential energy and the work done by the water on the object remains the same. Hence, the value of *v* in practice is smaller than that in **(b)(ii)**.	[1] [1]
3(a)	Yes as there is a constant phase difference between the two waves.	[1]
3(b)	The two waves meet in antiphase at point X and thus destructive interference takes place and hence a minimum intensity is obtained. As the amplitude of the two waves are not equal, incomplete cancellation will take place at point X and hence, the resultant intensity is non-zero.	[1] [1]
3(c)(i)	$f = \frac{1}{T} = \frac{1}{0.8 \times 10^{-3}} = 1250$ Hz $\lambda = \frac{v}{f} = \frac{330}{1250} = 0.264$ m	[1] for correct *f* [1] for correct λ
3(c)(ii)	$x = \frac{\lambda D}{a} = \frac{(0.264)D}{0.20}$ Distance OX = $\frac{1}{2}x = \left(\frac{1}{2}\right)\frac{(0.264)D}{0.20}$ $2.4 = \left(\frac{1}{2}\right)\frac{(0.264)D}{0.20}$ $D = 3.64$ m	[1] for correct expression [1] for recognizing that OX = 0.5*x* [1] for correct answer
4(a)(i)	As p.d. increases, the ratio of p.d. to current increases. This shows that resistance increases as p.d. increases.	[1] or any logical answer
4(a)(ii)	As p.d. across the lamp increases, power dissipation as heat increases, increasing the temperature of the filament. This leads to an increase in amplitude of vibration of lattice ions. This causes electrons to collide more frequently with the lattice ions. Hence *R* increases.	[1] [1]
4(b)(i)	In the day, the resistance of the LDR is 10 Ω. As the lamp is connected in parallel with the LDR, the effective resistance of two resistors connected in parallel will always be lower than the lower resistance of the two resistors. Hence, the effective resistance will always be less than 10 Ω. As this set of resistors is connected in series with a fixed resistor of 20 Ω, by potential divider principle, the p.d. across will always be less than 6 V, hence unable to attain normal working condition.	[1] [1]

4(b)(ii)	$R_{\text{lamp}} = \frac{6^2}{1.5} = 24\ \Omega$ $R_{\text{effective}} = 20\ \Omega$ $\frac{1}{R_{\text{effective}}} = \frac{1}{R_{LDR}} + \frac{1}{24}$ $\frac{1}{20} = \frac{1}{R_{LDR}} + \frac{1}{24}$ $R_{LDR} = 120\ \Omega$	[1] for R_{lamp} [1] for substitution [1] for correct answer
5(a)(i)	Root-mean-square of 20.0 A is the d.c. equivalence of an a.c. that will <u>provide the same heating effect</u> as a <u>d.c current of 20.0 A flowing through a resistor.</u>	[1]
5(a)(ii)	$\frac{N_p}{N_s} = \frac{I_s}{I_P}$ $\frac{3000}{N_s} = \frac{4}{20\sqrt{2}}$ $N_s = 21213 = 21000$	[1] for turns ratio formula [1] for correct answer
5(b)(i)	$\omega = 2\pi f = 380$ $f = 60.5$ Hz	[1] for correct answer
5(b)(ii)	$P_{\text{mean}} = I^2_{\text{r.m.s.}} R$ $300 = \left(\frac{4}{\sqrt{2}}\right)^2 R$ $300 = \frac{16}{2} R$ $300 = 8R$ $R = 37.5\ \Omega$	[1] for correct substitution [1] for correct answer
6(a)	$E = \frac{hc}{\lambda}$ $E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{350\times10^{-9}}$ $E \approx 5.68\times10^{-19}$ J $E \approx 3.55$ eV Since energy of photon is less than the work function, photoelectrons will not be emitted.	[1] for energy of a photon [1] for conclusion with explanation

6(b)	$P \times t = Nhf$ $\frac{N}{t} = \frac{P\lambda}{hc}$ $\frac{N}{t} = \frac{0.50 \times 350 \times 10^{-9}}{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}$ $\frac{N}{t} \approx 8.80 \times 10^{17}\ \text{s}^{-1}$	[1] for substitution [1] for correct answer
6(c)	$p = \frac{h}{\lambda}$ $p = \frac{6.63 \times 10^{-34}}{350 \times 10^{-9}}$ $p \approx 1.89 \times 10^{-27}\ \text{kg m s}^{-1}$ Since photons are not absorbed by the metal surface, they are assumed to be reflected normally away from the surface with the same magnitude of momentum. Force on photons by surface $= \frac{N\Delta p}{t}$ $= 8.80 \times 10^{17} \times \left[\left(-1.89 \times 10^{-27}\right) - \left(1.89 \times 10^{-27}\right)\right]$ $\approx -3.33 \times 10^{-9}\ \text{N}$ By Newton's third law, force on surface by photons $\approx 3.33 \times 10^{-9}\ \text{N}$ Hence, pressure on surface $= \frac{F}{A}$ $= \frac{3.33 \times 10^{-9}}{4.0 \times 10^{-7}}$ $\approx 8.33 \times 10^{-3}\ \text{Pa}$	[1] for initial momentum [1] for calculation of force [1] for correct answer [Note: Subtract 1 mark if presentation is unclear]
6(d)	When intensity is increased, the <u>energy of one photon remains the same</u> since the wavelength remains the same. Hence, the answer in (a) is <u>unaffected</u>.	[1]
7(a)	Let the mass of the satellite be *m*. According to Newton's Law of Gravitation, $F_G = \frac{GMm}{r^2}$ When the satellite orbits around the planet in a circular orbit, the gravitational force acting on the satellite by the planet serves as the centripetal force for the orbit. Therefore,	

	$F_C = F_G$ $mr\omega^2 = \frac{GMm}{r^2}$ $mr\left(\frac{2\pi}{T}\right)^2 = \frac{GMm}{r^2}$ $T^2 = \frac{4\pi^2}{GM}r^3$	[1] for equating F_C to F_G [1] for correct manipulation
7(b)	Rhea: $\lg T = \lg(0.389\times10^6) = 5.59$ $\lg r = \lg(0.527\times10^9) = 8.72$ Titan: $\lg T = \lg(1.38\times10^6) = 6.14$ $\lg r = \lg(1.22\times10^9) = 9.09$	[1] for correct values for lg T [1] for correct values for lg r
7(c)1. **7(c)2.**		[1] for correct plot of both points [1] for good line of best fit

7(d)(i)	$\text{gradient} = \dfrac{6.60 - 5.11}{9.40 - 8.40}$ $= \dfrac{1.49}{1.00}$ $= 1.49$	[1] for correct substitution [1] for correct value approximate to 1.5
7(d)(ii)	The moons of Saturn which orbit in circular paths must obey $T^2 = \dfrac{4\pi^2}{GM} r^3$. Linearising this equation will lead to the equation $\lg T = \dfrac{1}{2}\lg\dfrac{4\pi^2}{GM} + \dfrac{3}{2}\lg r$. On a graph showing the variation of $\lg T$ with $\lg r$, this equation is represented by a straight line with a gradient of 1.5. Since the gradient of the graph in Fig 7.2 is 1.49, the major moons of Saturn can be considered to orbit in circular paths.	[1] linearise the equation [1] to recognise that gradient obtained is similar to theory
7(e)	$\lg(3.78 \times 10^8) = 8.58$ From the graph, the corresponding value for $\lg T$ is 5.38. Hence, $T = 10^{5.38} = 2.40 \times 10^5$ s	[1] [1]
7(f)(i)	From Fig. 7.2, $\lg T = 0.5\lg\dfrac{4\pi^2}{GM} + 1.49\lg r$ Substituting (9.40, 6.60) $0.5\lg\dfrac{4\pi^2}{GM} = 6.60 - 1.49 \times 9.40$ $= -7.406$ $\lg\dfrac{4\pi^2}{GM} = -14.812$ $\dfrac{4\pi^2}{GM} = 10^{-14.812}$ $= 1.542 \times 10^{-15}$ $M = \dfrac{4\pi^2}{(6.67 \times 10^{-11})(3.664 \times 10^{-15})}$ $= 3.84 \times 10^{26}$ kg	[1] for correct equations and substitution [1] for correct answer (Note: mass of Saturn = 5.68×10^{26} kg
7(f)(ii)	Multiple sets of readings were used in calculating the mass in **(f)(i)**, as compared to only one set used in the student's calculation. Using multiple sets of readings help to reduce the random error through the use of a best fit line. This means that the student's calculation will be less accurate than the values calculated in **(f)(i)**.	[1] [1]

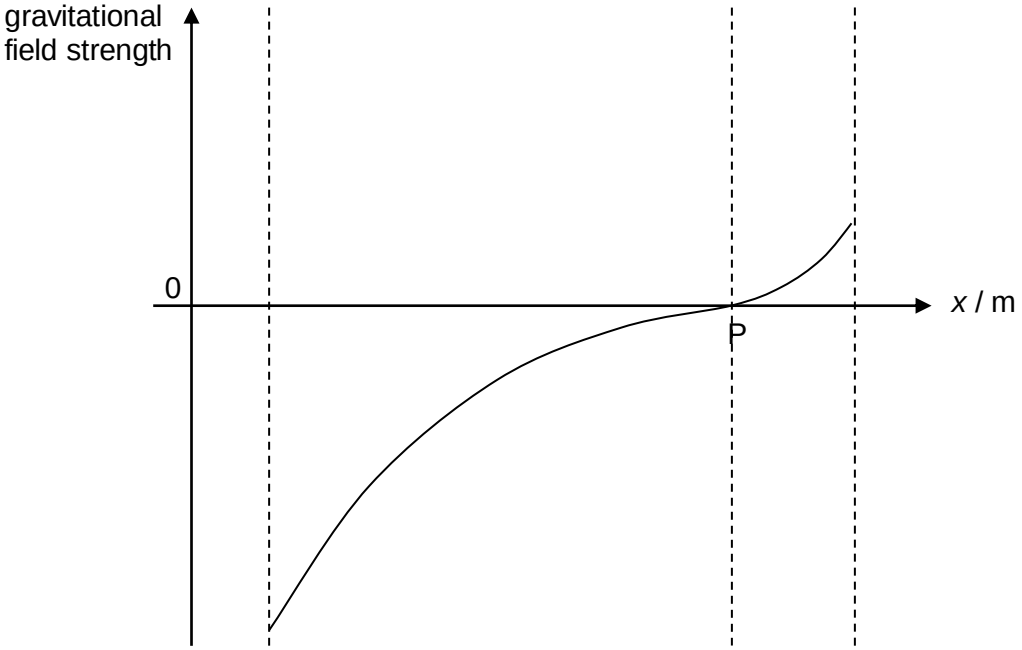
8	**Aim** : To investigate how the magnetic force on 2 parallel wires depends on the current through them, by determining the constants *n* and *k*.	
	Independent variable : current I, measured by ammeter	[1] correct indep and dep variables
	Dependent variable : magnetic force *F*, calculated	
	Controlled variables: - separation between 2 wires - length of 2 wires	[1] two correct controlled variables
	Diagram :	
		[1] show how two wires are kept straight and parallel [1] show how electronic balance detects magnetic force
		[1] electric circuit
	Procedure : a) Set up the apparatus as shown above. b) Measure and record m_o, the electronic balance reading when no current is flowing through both wires. c) Close circuit and pass a current through the wires. Measure and record the ammeter reading I. d) Measure and record *m*, the electronic balance reading. e) Calculate the magnetic force *F* using $F = (m - m_o)g$ where *g* is the acceleration of free fall. f) Vary the rheostat and repeat the steps to obtain 6 sets of readings for *m*, I and *F*. g) $F = k I^n$ $\lg F = n \lg I + \lg k$ Plot a graph of lg *F* versus lg I.	[1] how to obtain I [1] how to determine *F* [1] for coherent of procedure (e.g. if student leave out (f), consider not coherent)

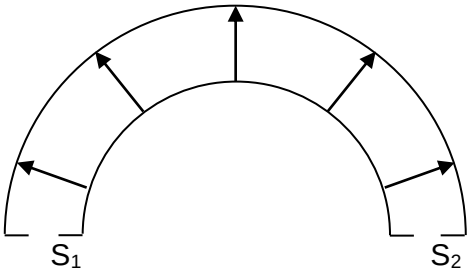
	k and *n* can be obtained as follows: *n* =gradient of graph $k = 10^{\text{vertical intercept}}$ **<u>Further details</u>** : *Precautions to improve accuracy :* - Use a spirit level to check that the both wire are horizontal. - For each value of I, repeat the experiment to obtain average *F*. - Keep the separation between the 2 wires small (2—3cm) so that the magnetic force is not too small. - *Safety precautions* : - The current required to provide a measurable force can be quite large. Hence all wires must be insulated to prevent any electrical shock. - Open the circuit when not taking measurement so as to prevent overheating of the wires.	[1] how to determine *n* [1] how to determine *k* [1] any one [1] any one

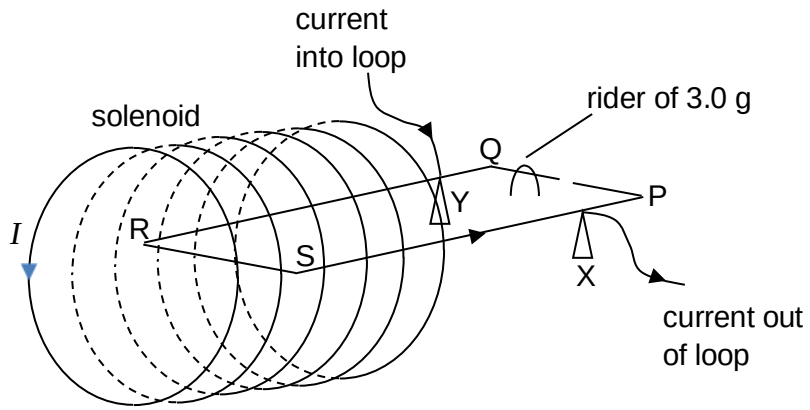
Answers to JC2 Preliminary Examination Paper 3 (H2 Physics)

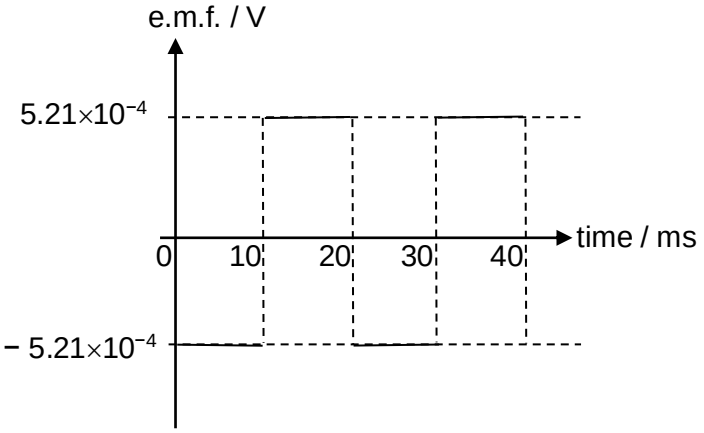
Suggested Solutions:

No.	Solution	Remarks
1(a)	For the ship, Using $v = u + at$, $0 = (11.0) + (-a)t$ $a = \frac{11.0}{t}$ $s_1 = (11.0)t + \frac{1}{2}(-a)(t)^2$ For the iceberg, $s_2 = (1.0)t$ Thus, $s_1 + s_2 = 499$ m $(11.0)t + \frac{1}{2}(-a)(t)^2 + (1.0)t = 499$ $(11.0)t + \frac{1}{2}(-\frac{11.0}{t})(t)^2 + (1.0)t = 499$ $t = 76.8$ s $a = \frac{11.0}{t} = \frac{11.0}{76.8} = 0.143$ m s^{-2} $F = ma = \left(2.4 \times 10^4\right)\left(0.14\right) = 3.4 \times 10^3$ N	[1] for correct equation for a [1] for correct equations for s_1 and s_2 [1] for correct $s_1 + s_2$ [1] for correct answer
1(b)(i)	Assume the ship is moving towards the right. Applying conservation of momentum and taking to the right as positive, $\left(2.4 \times 10^4\right)(11.0) + m_{iceberg}\left(-1.0\right) = \left(2.4 \times 10^4 + m_{iceberg}\right)\left(-0.8\right)$ $m_{iceberg} = 1.4 \times 10^6$ kg	[1] for correct conservation of momentum equation [1] for correct answer
1(b)(ii)	$F = \frac{\Delta p}{t} = \frac{\left(1.4 \times 10^6\right)\left(-0.80 - \left(-1.0\right)\right)}{1.5} = 1.9 \times 10^5$ N	[1] for change in momentum [1] for correct answer
2(a)(i)	Gravitational potential at a point is the <u>work done per unit mass</u> by an external agent in bringing the mass <u>from infinity to that point</u> at constant speed.	[1] for key phrases
2(a)(ii)	Gravitational force is an <u>attractive force and the external force is opposite in direction to the gravitational force</u> so that the mass will move at constant speed. The external force is in the <u>opposite direction to the displacement</u> as a mass is brought from infinity to a point. Hence, work done is negative and so the value of potential is negative at all points.	[1] for appreciating that external force is opposite to gravitational force, which is attractive in nature [1] for explaining why work done is negative

2(b)(i)	The resultant gravitational field strength can be obtained by determining the <u>negative of the gradient</u> at any point from the graph.	[1] for key phrase
2(b)(ii)	Let d be the distance from the centre of the Earth. At point P, the resultant gravitational field strength is zero. $g_E = g_M$ $\frac{GM_E}{d^2} = \frac{GM_M}{\left[\left(3.8\times10^8\right)-d\right]^2}$ $\frac{6.0\times10^{24}}{d^2} = \frac{7.4\times10^{22}}{\left[\left(3.8\times10^8\right)-d\right]^2}$ $d \approx 3.4\times10^8$ m	[1] for substitution [1] for answer
2(b)(iii)		[1] for graph
2(c)	The spacecraft will be provided with just enough energy for it to reach slightly beyond point P. Beyond point P, the spacecraft will be pulled towards Moon due to the resultant gravitational field pointing towards the Moon. For spacecraft to just reach point P, loss in k.e. = gain in g.p.e. $\frac{1}{2}mv_E^2 - \frac{1}{2}mv_P^2 = m\phi_P - m\phi_E$ Since $v_P > 0$, $\frac{1}{2}v_E^2 > \left[-1.3-\left(-62.3\right)\right]\times10^6$ $v_E > 1.1\times10^4$ m s^{-1}	[1] for clear explanation [1] for substitution [1] for answer

3(a)	loss in e.p.e. = gain in k.e. $qV_1 - qV_2 = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$ $-1.60\times10^{-19}\times-200 = \frac{1}{2}\times9.11\times10^{-31}\times\left[v_2^2 - \left(4.0\times10^6\right)^2\right]$ $v_2 \approx 9.29\times10^6\ \text{m s}^{-1}$	[1] for substitution [1] for answer
3(b)(i)	There is an electric force acting on the electron towards the centre of circle, which causes the electron to experience an acceleration. The direction of the electric force is always perpendicular to the direction of displacement of the electron. Hence, the electric force causes the electron to change its direction of motion, and to move in a circular path at constant speed.	[1] for explaining presence of electric force and direction [1] for constant speed due to force and displacement being perpendicular to each other
3(b)(ii)		[1] for evenly spaced field lines pointing radially outwards
3(b)(iii)	The electric force provides the centripetal force necessary for electron to move in a circle. $qE = \frac{mv^2}{r}$ $1.60\times10^{-19}\times2.0\times10^3 = \frac{9.11\times10^{-31}\times\left(9.29\times10^6\right)^2}{r}$ $r = 0.246\ \text{m}$	[1] for substitution [1] for answer

4(a)(i)		[1]
4(a)(ii)	Let length SP be L and width RS be x. By the principle of moment, $(B_1 I_1 x)(0.75\ L) = (mg)(0.25\ L)$ $(B_2 I_2 x)(0.50\ L) = (mg)(0.50\ L)$ $\left(\frac{B_1}{B_2}\right)\left(\frac{I_1}{I_2}\right)\left(\frac{0.75}{0.50}\right) = \left(\frac{0.25}{0.50}\right)$ $\left(\frac{I_1}{I_2}\right)\left(\frac{I_1}{I_2}\right)\left(\frac{0.75}{0.50}\right) = \left(\frac{0.25}{0.50}\right)$ $\frac{I_1}{I_2} = 0.577$	[1] for correct application of POM for both currents [1] for correct substitution [1] for correct answer
4(b)(i)	$E = \left\lvert -\frac{d\Phi}{dt} \right\rvert$ $= \frac{d(NBA)}{dt}$ $= NA\frac{dB}{dt}$ $= NA\frac{d(\mu_o nI)}{dt}$ $= NA\mu_o n\frac{dI}{dt}$ $= (9)(0.010 \times 0.018)(4\pi \times 10^{-7})(\frac{400}{0.50})(\frac{3.2}{10 \times 10^{-3}})$ $= 5.21 \times 10^{-4}$ V	[1] for correct substitution [1] for correct answer

4(b)(ii)		[1] for correct e.m.f. values [1] for correct shape and direction of V
5(a)(i)	A metastable state allows an electron to stay at its excited state for a longer lifetime. This allows population inversion to occur where there are more excited electrons than ground state electrons. Stimulated emission will thus occur for these excited electrons at the metastable state producing a bulk of photons.	[1] stay for a longer lifetime [1] population inversion [1]stimulated emission
5(a)(ii)	Energy that is contained per pulse is $E = Pt = (6.0)\left(30\times10^{-3}\right)$ = 0.18 J $E = \frac{Nhc}{\lambda}$ where N is the number of photons per pulse $\therefore N = \frac{E\lambda}{hc} = \frac{(0.18)\left(680\times10^{-9}\right)}{\left(6.63\times10^{-34}\right)\left(3.0\times10^{8}\right)} \approx 6.15\times10^{17}$	[1] energy per pulse [1] for correct answer
5(b)	When p-type and n-type materials are placed in contact with each other, some of the free electrons from the donor (n-type) impurity atoms begin to migrate or diffuse across this junction and fill up or neutralise the holes in the p-type material. Since the regions on either sides of the junction are now completely depleted of free charge carriers in comparison to the p- and n-type materials further away from the junction, this area around the junction is now called the depletion layer or depletion zone or depletion region.	[1] diffusion of charges [1] free of charge carriers
6(a)	Simple harmonic motion is an oscillatory motion in which the acceleration of an object is proportional to the displacement of the object from its equilibrium position, and is always directed towards that position (or opposite to its displacement).	[1] $a \propto x$ [1] a, x opposite direction

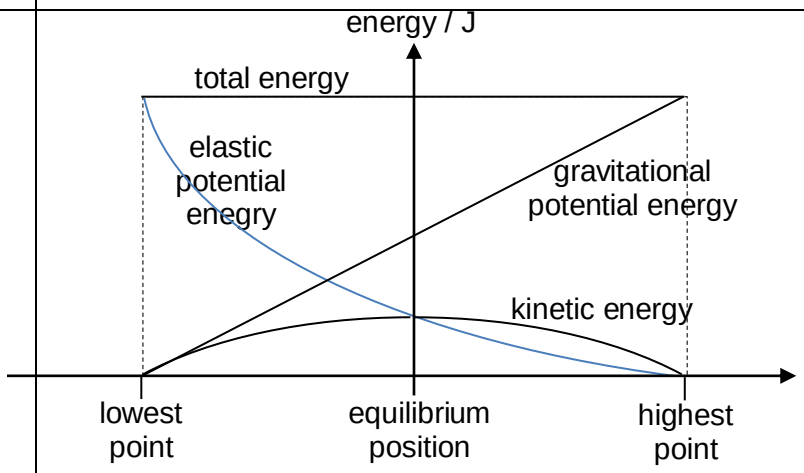
6(b)(i)	At equilibrium, $kx = mg$ $k(0.050) = (0.500)(9.81)$ $k = 98.1 \text{ N m}^{-1}$	[1] substitution [1] correct answer
6(b)(ii)	Loss in g.p.e= mgh = (0.500)(9.81)(0.050) = 0.245 J	[1] correct answer
6(b)(iii)	gain in e.p.e. $= \frac{1}{2}kx^2$ $= \frac{1}{2}(98.1)(0.050)^2$ $= 0.123$ J	[1] correct answer
6(c)(i)1.	$F = kx$ $= (98.1)(0.100)$ $= 9.81$ N	[1] correct answer
6(c)(i)2.	$F = kx$ $= (98.1)(0)$ $= 0$ N	[1] correct answer
6(c)(ii)	At lowest point, taking downwards as positive, $ma = mg - kx$ $(0.500)a = (0.500)(9.81) - (98.1)(0.100)$ $a = -9.81 \text{ m s}^{-2}$ $a_o = -\omega^2 x_o$ $(-9.81) = -\omega^2(0.050)$ $\omega = 14.0 \text{ rad s}^{-1}$	[1] for acceleration [1] for correct answer
Or	At highest point, taking upwards as positive, $ma = kx - mg$ $(0.500)a = (98.1)(0) - (0.500)(9.81)$ $a = -9.81 \text{ m s}^{-2}$ $a_o = -\omega^2 x_o$ $(-9.81) = -\omega^2(0.050)$ $\omega = 14.0 \text{ rad s}^{-1}$	
6(c)(iii)1.	At equilibrium position, $v = \pm\omega\sqrt{(x_o^2 - x^2)}$ $= \pm(14.0)\sqrt{(0.050^2 - 0^2)}$ $= \pm 0.700 \text{ m s}^{-1}$	[1] correct answer

<table>
<tr>
<td>6(c)(iii)2.</td>
<td>At equilibrium position,
$\text{max. } k.e. = \frac{1}{2}mv^2$
$= \frac{1}{2}(0.500)(0.700)^2$
$= 0.123 \text{ J}$</td>
<td>[1] correct answer</td>
</tr>
<tr>
<td>6(d)</td>
<td>
<table>
<tr><th></th><th>E_{GPE} / J</th><th>E_{EPE} / J</th><th>E_K / J</th><th>E_T / J</th></tr>
<tr><td>lowest point</td><td>0</td><td>0.491</td><td>0</td><td>0.491</td></tr>
<tr><td>Eq point</td><td>0.245 (e.c.f.)</td><td>0.123 (e.c.f.)</td><td>0.123J (e.c.f.)</td><td>0.491</td></tr>
<tr><td>highest point</td><td>0.491</td><td>0</td><td>0</td><td>0.491</td></tr>
</table>
$E_{GPE} = mgh$
$E_{EPE} = \frac{1}{2}kx^2$
$E_K = \frac{1}{2}mv^2$
$E_T = E_{GPE} + E_{EPE} + E_K$
</td>
<td>[1] for E_{GPE}, E_{EPE}, E_K, at equilibrium (e.c.f. if values were computed in previous parts)

[1] for all 3 correct E_T

[1] for the 3 zero energies

[1] for E_{EPE} at lowest point. No e.c.f.

[1] for E_{GPE} at highest point. No e.c.f.</td>
</tr>
<tr>
<td>6(e)</td>
<td> 
</td>
<td>[1] for correct shape of E_T , E_{GPE}

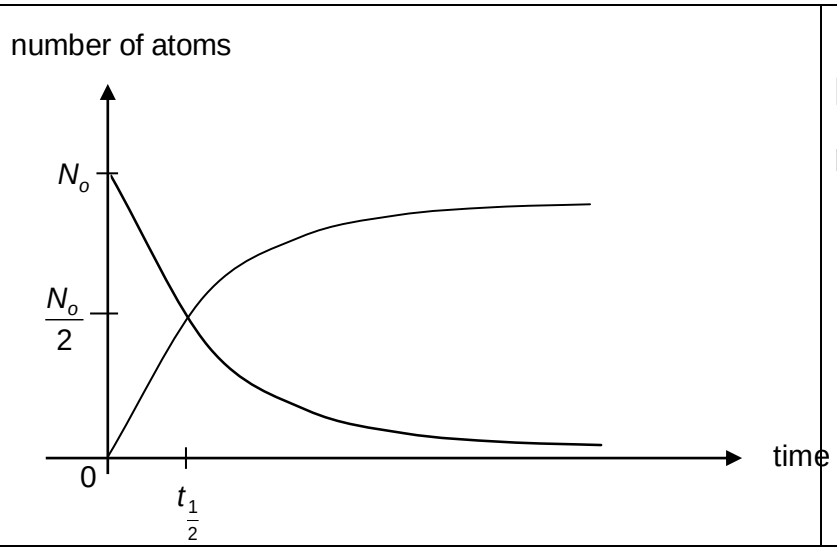
[1] for correct shape of E_{EPE}

[1] for correct shape of E_K and coincide the E_{EPE} graph at y-axis</td>
</tr>
<tr>
<td>7(a)(i)</td>
<td>An ideal gas is a gas that obeys the ideal gas equation of $pV = nRT$</td>
<td>[1] for correct definition</td>
</tr>
<tr>
<td>7(a)(ii)</td>
<td>Amount of gas in moles, pressure of gas, volume of gas and thermodynamic temperature</td>
<td>[2]
deduct 1 for every missing quantities</td>
</tr>
</table>

7(b)(i)	Amount of gas in moles in X, $n_X = \frac{p_X V_X}{RT_X} = \frac{(5\times10^7)(2\times10^{-3})}{(8.31)(177+273.15)} = 26.7 \text{ mol}$ Amount of gas in moles in Y, $n_Y = \frac{p_Y V_Y}{RT_Y} = \frac{(1.5\times10^7)(4.5\times10^{-3})}{(8.31)(27+273.15)} = 27.1 \text{ mol}$	[1] no of moles for X [1] no of moles for Y
7(b)(ii)	Since volume of gas in X expanded, according to First law of thermodynamics, there will be a negative work done on gas in X. Since there is no heat supplied or removed from system, Q is zero. By First law of thermodynamics, $\Delta U = Q + W$, since W is negative, change in internal energy is negative, therefore temperature of gas decreases.	[1] work done on gas negative [1] using first law to explain negative change in internal energy
7(b)(iii)	Total number of gas in cylinder should remain the same even when partition is removed. $n_{final} = n_X + n_Y = 53.816$ moles $n_{final} = \frac{p_{final} v_{final}}{RT_{final}} = \frac{(3\times10^7)(6.5\times10^{-3})}{(8.31)(T_{final})} = 53.816$ $T_{final} = 436$ K	[1] show understanding that tot no of gas atoms are the same [1] correct substitution [1] correct answer
7(b)(iv)1.	$\frac{P_i}{P_f} = \frac{n_i}{n_f}$ $\frac{P}{0.97P} = \frac{26.74+27.076}{n_f}$ $n_f = 52.2$ moles Number of gas atoms that remains = 3.14×10^{25} atoms.	[1] final number of moles [1] number of atoms
7(b)(iv)2.	Number of gas atoms that escape $(53.816-52.2)(6.02\times10^{23})$ $= 9.73\times10^{23}$ Rate of escape $= \frac{9.73\times10^{23}}{35\times24\times3600}$ $= 3.22\times10^{17}$ s^{-1}	[1] no of atoms remaining [1] rate of escape
7(b)(iv)3.	The pressure in the cylinder was higher initially; therefore the rate of escape of gas atoms is higher. As pressure becomes lower, the rate of escape will be lower. Therefore over period of 35 days, the rate of escape should be an average.	[1] correct answer

7(c)(i)	Determine the PV values at W and X. If they are the same, process will be isothermal. $P_W V_W = (2.1\times10^4)\times(2.1\times10^{-3}) = 44.1\ \text{kg m}^2\ \text{s}^{-2}$ $P_X V_X = (1.4\times10^4)\times(2.7\times10^{-3}) = 37.8\ \text{kg m}^2\ \text{s}^{-2}$ Therefore it is not an isothermal process as the *PV* values are not equal.	[1] for calculation of *PV* values Or calculation of internal energy (both accepted) [1] correct conclusion
7(c)(ii)	$\Delta U_{WX} = Q + W$ $= 20.5 - 15.6$ $= 4.9\ \text{J}$ $\Delta U_{WX} = \Delta U_{WYX}$ $\Delta U_{WYX} = Q + W_{WYX}$ $W_{WYX} = (2.1\times10^4)(2.7-2.1)\times10^{-3} = 12.6\ \text{J}$ $\Delta U_{WYX} = Q + W_{WYX}$ $4.9 = Q + (-12.6)$ $Q = 17.5\ \text{J}$	[1] change in internal energy for W→X [1] for work done by gas W→Y [1] heat supplied
8(a)(i)	The neutrons emitted are to initiate further fission reactions with other uranium nuclei.	[1]
8(a)(ii)	Energy released $= b.e._{Ba} + b.e._{Kr} - b.e._U$ $227 = (8.5\times144) + (8.5\times90) - (b.e._U)$ $b.e._U = 1762\ \text{MeV}$ Therefore, the binding energy per nucleon of uranium-235 $= \frac{1762}{235}$ $\approx 7.50\ \text{MeV}$	[2] for binding energy of uranium [1] for answer
8(a)(iii)	Nuclear binding energy of a nucleus is the minimum amount of energy required to break the nucleus into its constituent particles. It is also the energy released when a nucleus is formed. When uranium reacts with neutron, 1762 MeV of energy is required to break up uranium into its constituent particles. When barium and krypton are formed from the constituent particles, 1989 MeV of energy is released. Since more energy is released than is required, there is a net energy release of 227 MeV for the reaction.	[1] for concept of nuclear binding energy [1] for applying concept to equation [1] for conclusion

8(a)(iv)	Energy released in one hour due to nuclear reactions $= P \times t$ $= \frac{10^7 \times 100}{10} \times 3600$ $= 3.6 \times 10^{11}$ J Number of nuclear reactions required $= \frac{3.6 \times 10^{11}}{227 \times 10^6 \times 1.60 \times 10^{-19}}$ $\approx 9.91 \times 10^{21}$ Mass of uranium-235 consumed per hour $\approx 9.9119 \times 10^{21} \times 235 \times 1.66 \times 10^{-27}$ ≈ 3.87 g	[1] for calculating amount of energy released [1] for calculating number of reactions required [1] for answer
8(b)(i)	${}^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He$	[1]
8(b)(ii)	This is because radioactive decay is a spontaneous and random process.	[1]
8(b)(iii)	By conservation of momentum, $m_U v_U = m_{He} v_{He}$ $\frac{\text{intitial kinetic energy of } \alpha\text{-particle}}{\text{initial kinetic energy of uranium-235}}$ $= \frac{\frac{p_{He}{}^2}{2m_{He}}}{\frac{p_U{}^2}{2m_U}}$ $= \frac{p_{He}{}^2 m_U}{p_U{}^2 m_{He}}$ $= \frac{m_U}{m_{He}}$ $= \frac{235}{4}$ ≈ 59	[1] for applying conservation of momentum [1] for manipulation [1] for answer
8(b)(iv)1.	$N = N_o e^{-\lambda t}$ $1 = 6e^{-\frac{\ln 2}{2.4 \times 10^4} \times t}$ $t \approx 6.2 \times 10^4$ years	[1] for substitution [1] for answer
8(b)(iv)2.	Plutonium or uranium is not a by-product of any other nuclear reactions in the sample. Uranium is stable and does not decay.	[1] [1]

8(b)(v)		[1] for shape, and point at $\left(t_{\frac{1}{2}}, \frac{N_o}{2}\right)$

Centre Number	Index Number	Name	Class
3016			

RAFFLES INSTITUTION
2016 Preliminary Examination

PHYSICS **9646/02**
Higher 2

15 September 2016
Paper 2 Structured Questions **1 hour 45 minutes**

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, 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 staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains questions 1 to 6.**

For Examiner's Use	
1	/ 10
2	/ 12
3	/ 8
4	/ 10
5	/ 5
6	/ 15
7	/ 12
Deduction	
Total	/ 72

This booklet consists of **18** printed pages including the cover page.

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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	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	=	$R_1 + R_2 + \ldots$
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	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

1 **(a)** The velocity of a passenger aircraft changes from $220\ \text{m s}^{-1}$ due North to $240\ \text{m s}^{-1}$ due Northeast. Determine the magnitude of the change in the velocity of the aircraft.

magnitude of change in velocity = ... m s^{-1} [2]

(b) A police car is parked alongside a road in a school zone when a van exceeding the designated speed limit passes by at a constant speed of $20\ \text{m s}^{-1}$. The police car immediately gives chase with a constant acceleration of $2.5\ \text{m s}^{-2}$ and eventually overtakes the van.

(i) Calculate the distance travelled by the police car before it overtakes the van.

distance = m [2]

(ii) On Fig. 1.1, sketch well labelled graphs to show the variation with time of the displacement of the van and the police car from the instant the police car gives chase to the time it overtakes the van.

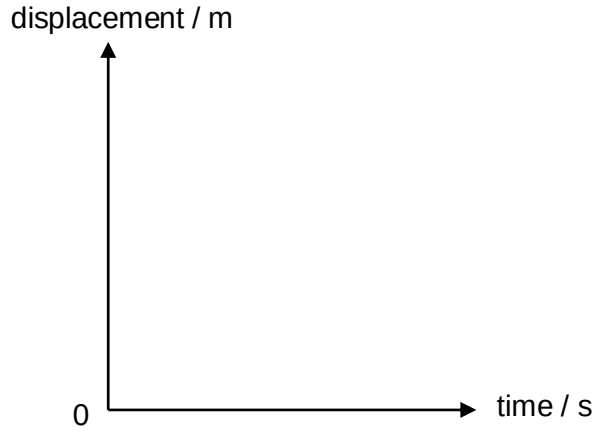


Fig. 1.1

[2]

(iii) At the point of overtaking the van, the policeman notices a fallen tree 130 m ahead. The police car continues to accelerate for 0.30 s before he applies the brakes. The maximum deceleration of the police car is 8.0 m s^{-2}.

1. Show that the speed of the police car is 41 m s^{-1} when the brakes are applied

[1]

2. Determine whether the police car manages to stop in time before colliding into the tree. Show all calculations clearly.

.....

.....

[3]

2 Fig. 2.1 shows two radio wave emitters S_1 and S_2 placed 45 m apart at the same horizontal level. They are driven by the same source. The radio waves are emitted in phase and uniformly in all directions.

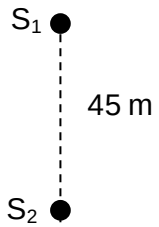


Fig. 2.1

(a) A man with a radio wave detector, walks steadily along the line joining S_1 and S_2 and detects a series of maximum and minimum intensity.

(i) With reference to the superposition of the waves emitted by S_1 and S_2, explain clearly why there is a fluctuation in intensity along the line S_1S_2.

.....

.....

.....

.....

..... [2]

(ii) Given that the man detects minimum intensity at both S_1 and S_2, and a total of 9 maxima between them, deduce the wavelength of the radio waves.

wavelength = ... m [2]

(b) The man now moves anticlockwise around S_2, along the circumference of a circle with centre at S_2 and radius 45 m as shown in Fig. 2.2. A and B are points along the circular path of the man.

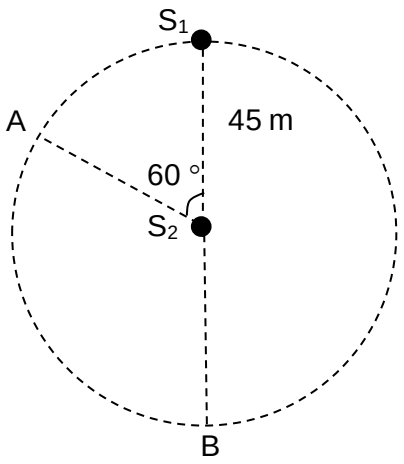


Fig. 2.2

(i) State whether the intensity at point A is a maximum or minimum.

intensity at point A is a ..... [1]

(ii) Deduce whether the intensity at point B is a maximum or minimum.

intensity at point B is a ..... [1]

(iii) Given that a is the amplitude of the wave from S_1 at point A, show that the intensity of the resultant wave at point B is proportional to $\frac{1}{4}a^2$.

[2]

(iv) On the axes provided in Fig. 2.3, sketch the variation of intensity along the circumference from A to B in the anticlockwise direction.



Fig. 2.3 [2]

(v) State how the variation of the intensity along AB would differ if the following changes were made independently.

1. Frequency of the source is reduced.

..... [1]

2. S_1 and S_2 are each connected to a different source such that the phase difference between the radio waves they emit is π radians, but having the same frequency and amplitude as before.

..... [1]

3 Fig. 3.1 shows the circuit of a simple ohm-meter. A milliammeter of resistance *r*, which gives full-scale deflection when a current of 5.00 mA flows through it, is connected to a 1.50 V cell of negligible internal resistance and a 297 Ω resistor.

The resistors, whose resistances are to be measured, are connected between the terminals A and B. When A and B are short-circuited, the milliammeter gives full-scale deflection.

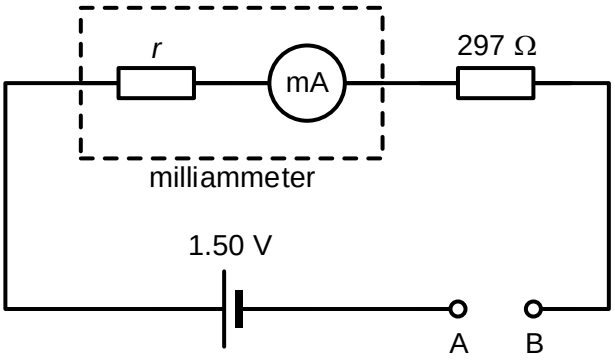


Fig. 3.1

(a) Calculate the resistance r of the milliammeter.

r = ... Ω [2]

(b) A resistor of unknown resistance R is connected between A and B. The milliammeter shows a deflection that is half of the full-scale. Calculate R.

R = ... Ω [2]

(c) Fig. 3.2 shows the scale of the milliammeter in mA.

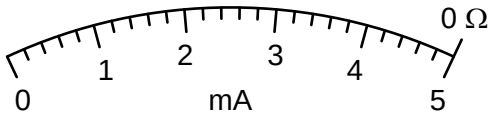


Fig. 3.2

Mark and label clearly on the scale in Fig. 3.2, the positions corresponding to R = 300 Ω, 900 Ω, 1200 Ω and a resistor of infinitely large resistance (mark as ∞). The position corresponding to 0 Ω has been marked on Fig. 3.2.

[2]

(d) State and explain whether the circuit is able to measure a resistance of 50 kΩ with good precision.

.....

.....

..... [2]

4 **(a)** State Einstein's photoelectric equation, explaining the meaning of the terms used.

equation:

.....

terms used:

.....

.....

[2]

(b) Fig. 4.1 shows the setup for an experiment on the photoelectric effect. X and Y are electrodes made of different metals placed in a vacuum glass chamber.

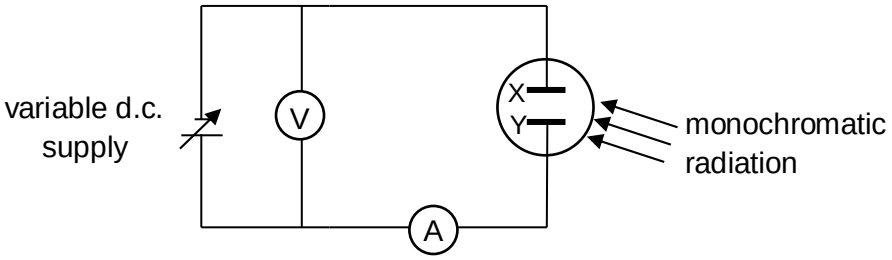


Fig. 4.1

X and Y are both illuminated by monochromatic radiation and the photocurrent I is measured as the potential difference across them is varied. Fig. 4.2 shows a graph of I against V where V is the potential of Y with respect to X.

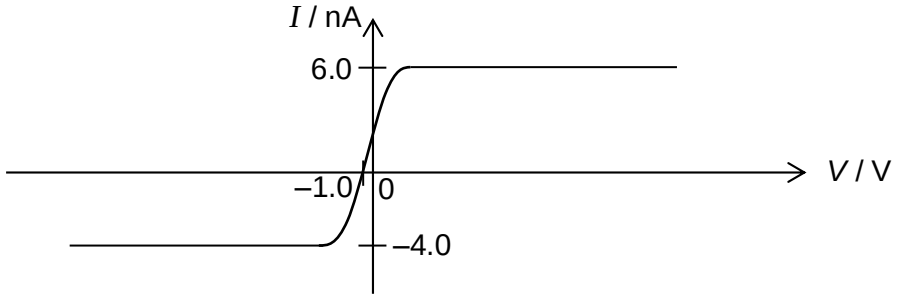


Fig. 4.2

(i) Explain why there is no current detected when $V = –1.0$ V.

.....

.....

[1]

(ii) Explain why there is a saturation current for values of $V < 0$ V.

.....

.....

.....

[1]

(iii) Fig. 4.3 shows information about the electrodes X and Y when they are illuminated by a certain monochromatic radiation.

electrode	surface area	work function	stopping potential
X	9.0×10^{-3} m^2	2.3 eV	1.84 V
Y	7.9×10^{-3} m^2	3.4 eV	0.74 V

Fig. 4.3

1. Calculate the energy of a photon of the incident radiation.

energy of photon = ... J [1]

2. For plate Y,

$$\frac{\text{rate of emission of photoelectrons}}{\text{rate of incidence of photons}} = 1.0 \times 10^{-6}.$$

Show that the intensity of the radiation falling on Y is 2.1 W m^{-2}.

[2]

(c) Electrons of energy 24.3 eV pass through an evacuated tube containing a cool gas. Fig. 4.4 shows the 5 lowest energy levels in an atom of the gas.

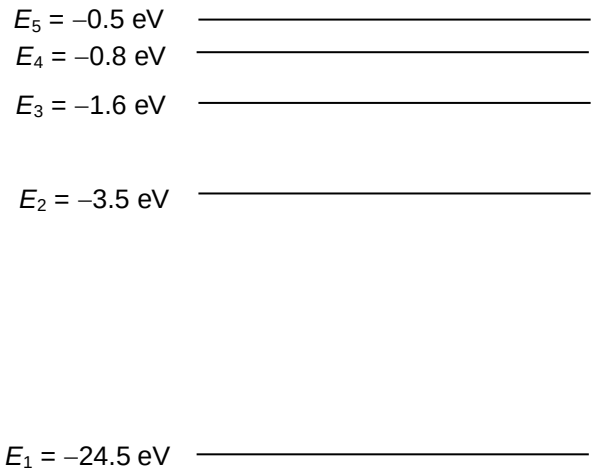


Fig. 4.4 (not to scale)

(i) State the number of spectral emission lines that might be produced by transitions among these levels.

..... [1]

(ii) Sketch, on Fig. 4.5, the pattern of the emission line spectrum which would be observable through a spectrometer. Label each line with the corresponding transition.

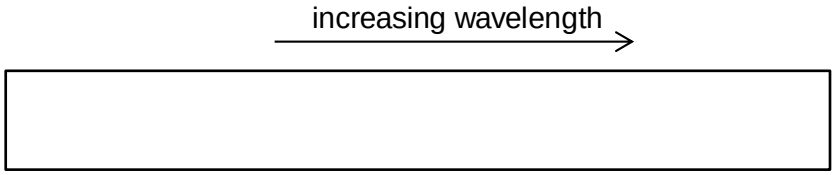


Fig. 4.5

[2]

5 **(a)** By reference to the band theory of electrical conduction in solids, explain why the electrical resistance of an intrinsic semiconductor material decreases as its temperature rises. You may draw a diagram if you wish.

.....

.....

.....

.....

.....

.....

.....

..... [3]

(b) Explain how doping an intrinsic semiconductor material, such as silicon, with Group 5 atoms changes its electrical conduction properties.

.....

.....

.....

..... [2]

6 A piston is attached to a massless spring in a frictionless cylinder of air as shown in Fig. 6.1. The cylinder is clamped tightly in place. The piston is then displaced downwards by a distance x from the equilibrium position and released. The piston-spring system starts to oscillate.

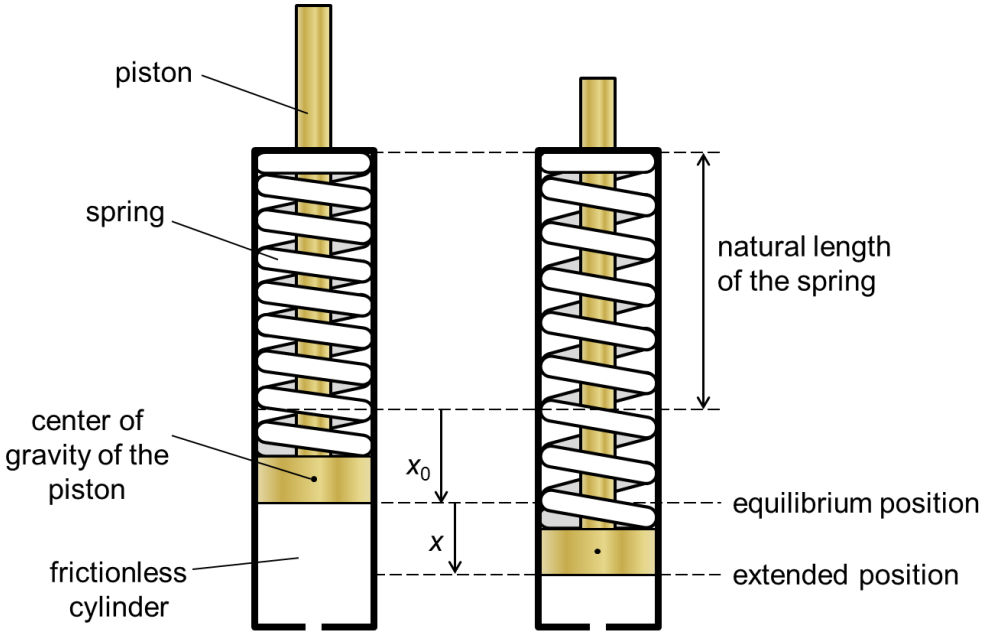


Fig. 6.1

(a) **(i)** On Fig. 6.2, draw and label the forces acting on the piston when the piston is displaced a distance x below the equilibrium position.



Fig. 6.2 [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]

(iii) Explain how the equation in **(a)(ii)** shows that the piston oscillates with simple harmonic motion.

.....

.....

.....

..... [2]

(b) The cylinder is now placed in a larger reserve cylinder that is filled with oil as shown in Fig. 6.3. The cylinders are clamped tightly in place

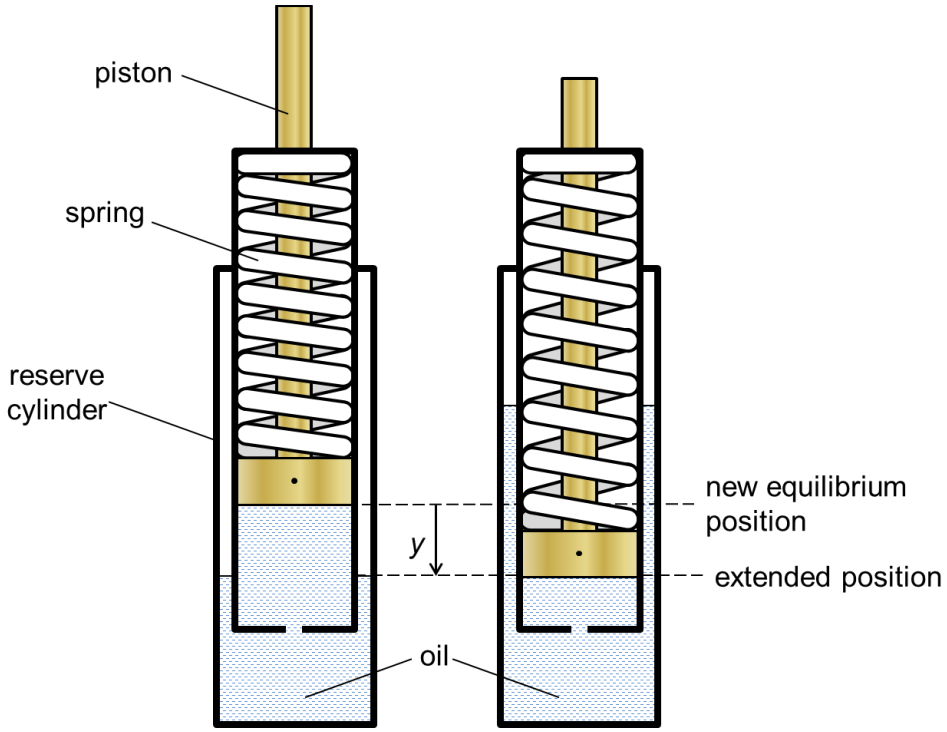


Fig. 6.3

The piston is displaced downwards with an initial displacement of y = 5.0 cm and released. The subsequent values of the displacement for the oscillation were recorded and plotted against time as shown in Fig. 6.4.

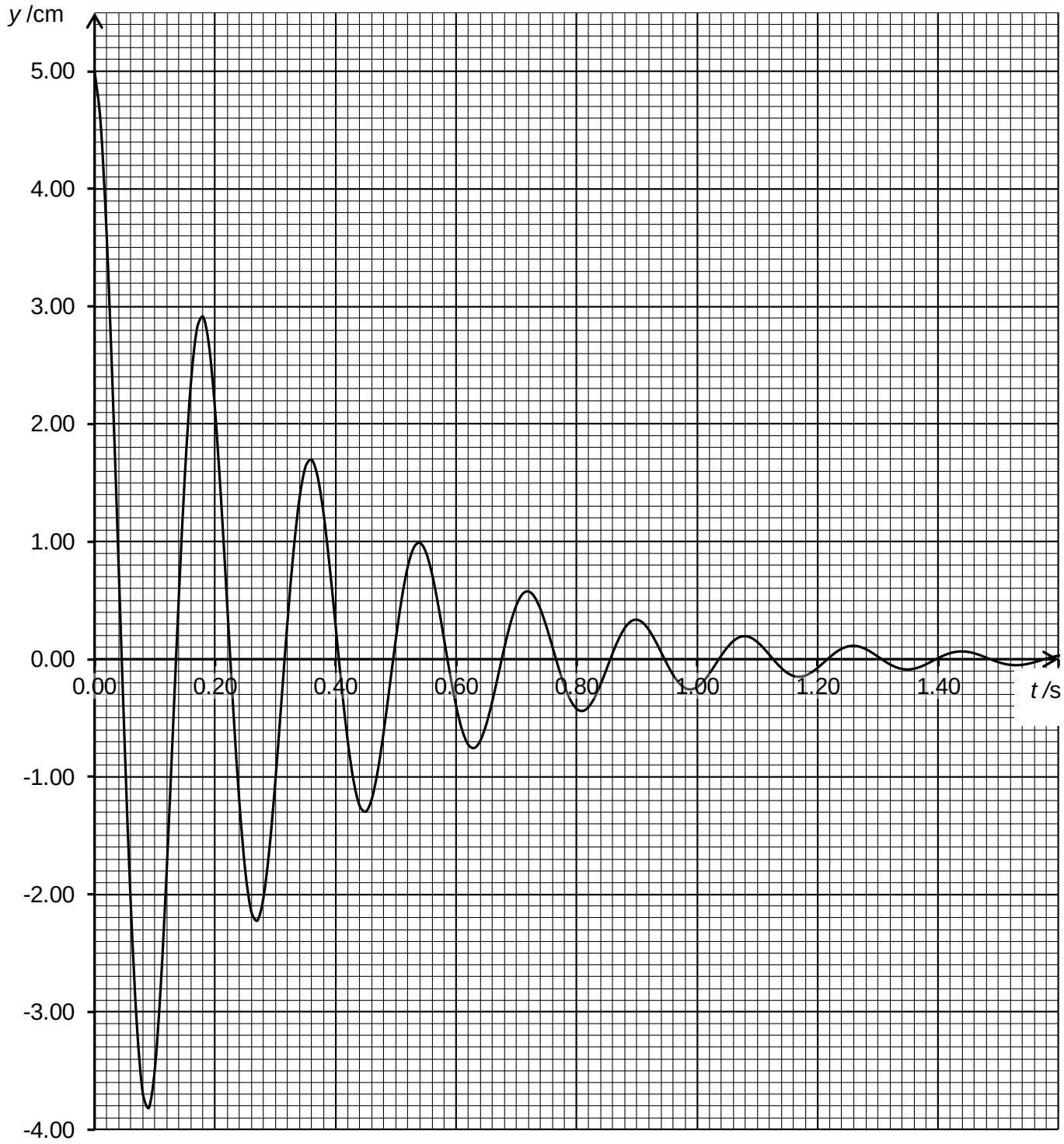

y /cm
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
t /s

Fig. 6.4

(i) With reference to Fig. 6.4,

1. deduce the amplitude of the oscillation of the piston at $t = 0.50$ s,

amplitude = ... cm [1]

2. explain why the amplitude of the oscillation of the piston decreases with time.

.....

..... [1]

(ii) It is suggested that the amplitude of the oscillation decreases exponentially with time according to the relationship

$$A = A_0 e^{-\gamma t}$$

where A_0 is the amplitude at the start of the oscillation,
A is the amplitude of the oscillation at any time t, and
γ is the damping coefficient of the system.

Fig. 6.5 shows some data from Fig. 6.4. of A and t

t / s	A / cm	ln (A / cm)
0.00	5.00	1.609
0.18		
0.36	1.70	0.531
0.54	1.00	0.000
0.72	0.60	–0.511
0.90	0.34	–1.079
1.08	0.20	–1.609
1.26	0.11	–2.303
1.44	0.07	–2.659

Fig. 6.5

Complete the table in Fig. 6.5. [1]

(iii) Fig. 6.6. shows a graph of ln A against t.

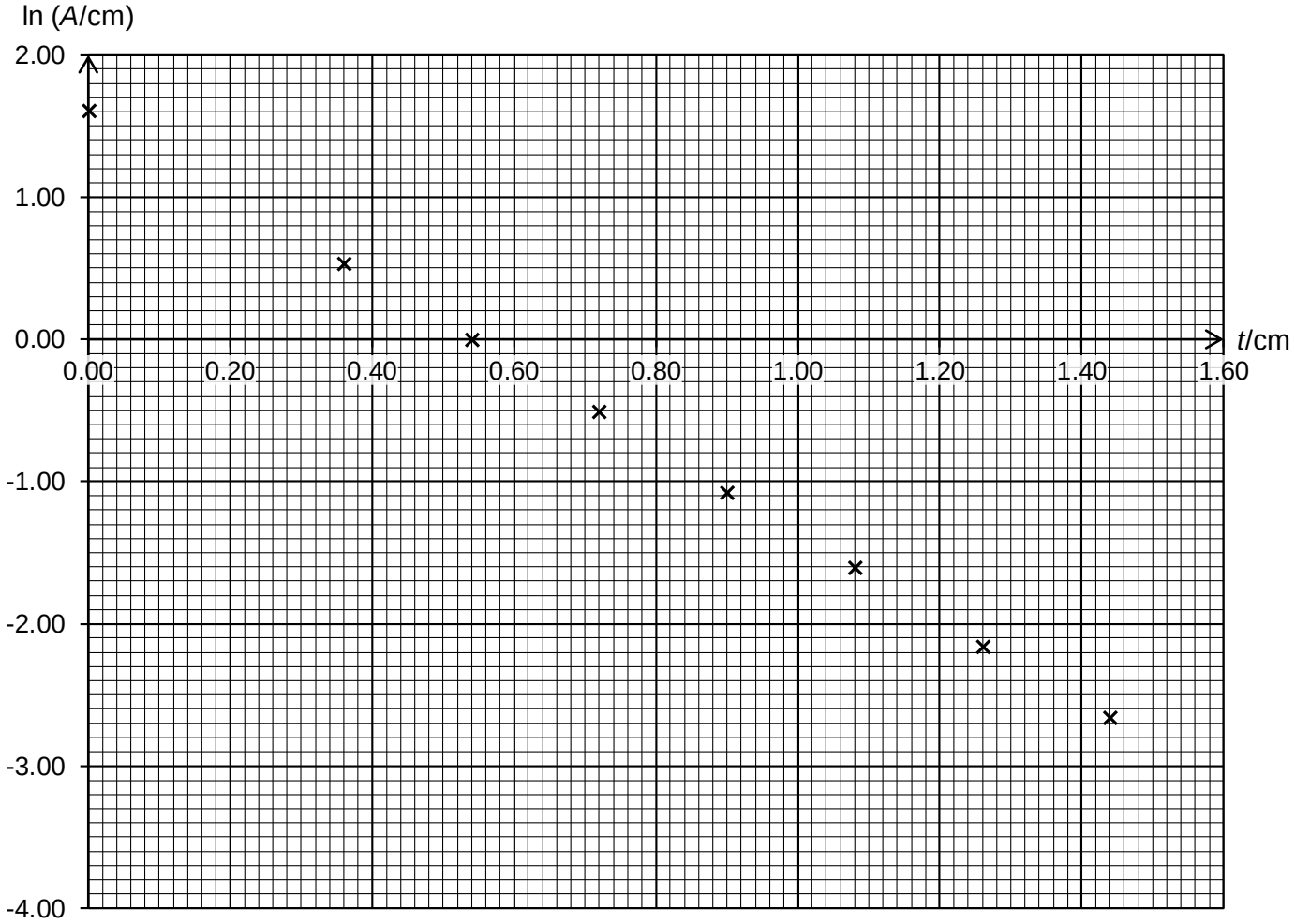


Fig. 6.6

1. Plot the point corresponding to $t = 0.18$ s on Fig. 6.6.

[1]

2. Draw the line of best fit for all the points on Fig. 6.6.

[1]

3. Use the equation in **(b)(ii)** and the line drawn in **(b)(iii)2.** to determine the magnitude of the damping coefficient γ of the system.

γ = ... s^{-1} [3]

(iv) On Fig. 6.7, sketch a graph to show the variation with time of the kinetic energy of the system. No further calculations are required.

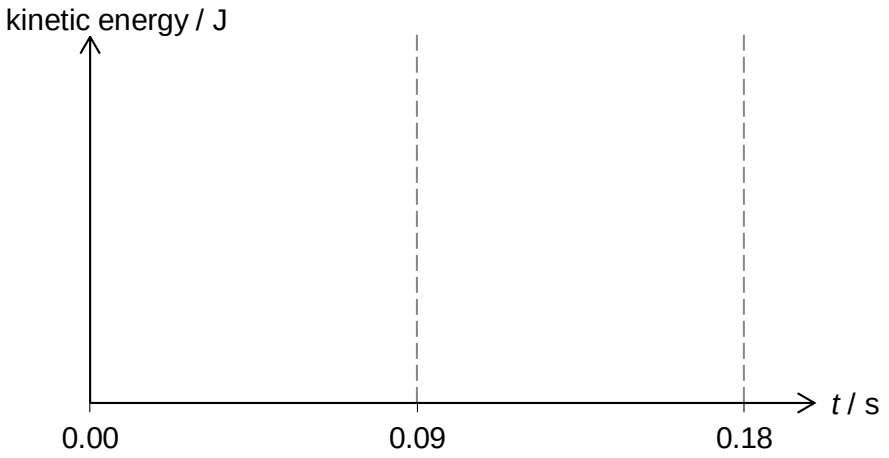


Fig. 6.7

[1]

(c) Damping systems like these are often used in motor vehicle suspension systems.

If the damping coefficient γ is a measure of the degree of damping of the system, suggest with a reason whether the magnitude of γ of the vehicle suspension system is likely to be higher or lower than that in **(b)**.

.....

..... [1]

End of Section

Centre Number	Index Number	Name	Class
3016			

RAFFLES INSTITUTION
2016 Preliminary Examination

PHYSICS **9646/02**
Higher 2

15 September 2016
Paper 2 Structured Questions **1 hour 45 minutes**

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, 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 staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains question 7.**

For Examiner's Use	
7	/ 12
Deduction	

This booklet consists of **5** printed pages including the cover page.

7 A suspension bridge is a bridge where the deck (the load-bearing portion) is hung using suspension cables. Fig. 7.1 shows a modern example of such a bridge.

There are several designs for suspension bridges, but all of these bridges share a similar feature. They use thick steel cables as suspension cables to support the weight of the bridge and the load on it.

As the load on the bridge is increased, the steel cables will extend by a small amount.

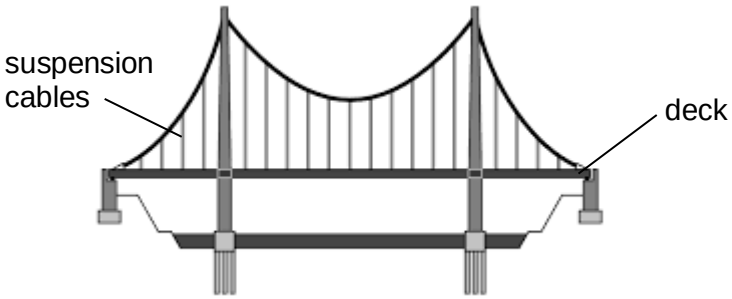


Fig. 7.1

A group of students are building a model of a suspension bridge and are considering using copper wires to support the deck. One property of the copper wires that they will need to study is the Young's modulus.

Young's modulus E is a mechanical property of linear elastic solid materials. It defines the relationship between stress (force per unit area) and strain (proportional deformation) in a material. It may be found using the equation

$$E = \frac{F}{A}\frac{L_0}{\Delta L}$$

where F is the force exerted on an object under tension,
A is the original cross-sectional area of the object through which the force is applied,
ΔL is the extension of the object when the force is applied,
L_0 is the original length of the object.

By investigating how the extension of a copper wire varies with the load applied to it, design an experiment to determine the Young's modulus E of copper.

You are provided with slotted masses, a mass hanger, a travelling microscope and a micrometer screw gauge. 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 small extension of the wire can be measured with sufficient precision,
(e) how E can be determined from the relationship between the variables,
(f) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Diagram

End of Section

RAFFLES INSTITUTION
2016 Preliminary Examination

PHYSICS **9646/01**
Higher 2

27 September 2016
Paper 1 Multiple Choice **1 hours 15 minutes**

Additional Materials: OMR Form

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your index number, name and class on the OMR Form. Shade the appropriate boxes.

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 OMR Form.

Read the instructions on the OMR 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 booklet consists of **20** printed pages including the cover page.

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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	v	=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

1 The following equation is used in an experiment to measure the viscosity η of a liquid in a pipe of radius r,

$$\eta = \frac{kr^2}{v}$$

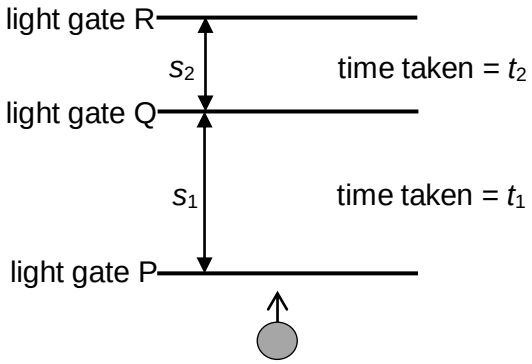
where k is a constant with a physical dimension of force per unit volume and v is the average speed of the fluid.

What are the base units of η?

A kg m^{-1} s^{-1} **B** kg m^{-1} s^{-3}

C kg m^{-2} s^{-1} **D** kg m^{-3} s^{-1}

2 An object is thrown vertically upwards and passes through three light gates P, Q and R as shown.



The object has a speed u when it passes P. It takes a time of t_1 to move up a distance s_1 between P and Q, and then takes a time of t_2 to travel a distance s_2 between Q and R. The object reaches its highest point exactly at R.

If the acceleration due to gravity is g, what is the distance $(s_1 + s_2)$ in terms of g, t_1 and t_2?

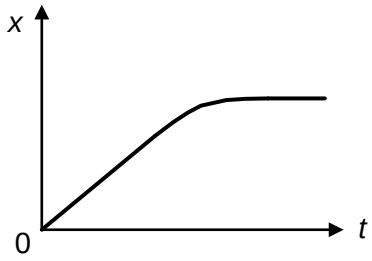
A $g(t_1 + t_2)$ **B** $g(t_1 + t_2)^2$

C $\frac{g(t_1 + t_2)^2}{2}$ **D** $\frac{(t_1 + t_2)^2}{2g}$

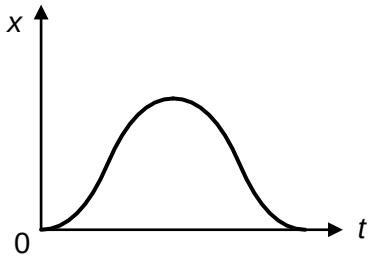
3 A ball bearing is released from rest 10 cm above a tall measuring cylinder which is filled with oil.

Which one of the following graphs best represents the variation with time t of displacement x of the ball bearing?

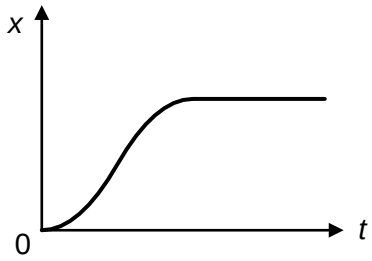
A



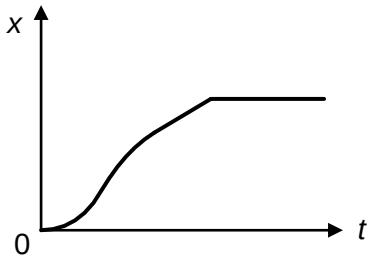
B



C



D



4 A man, carrying a large rock, sits in a boat on a lake. He drops the rock into the lake. The water level of the lake

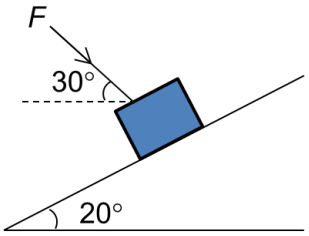
A increases because the density of the rock is larger than water hence the upthrust acting on it would be larger for equilibrium to occur.

B decreases because the density of the rock is larger than water and hence displaces a smaller volume of water as compared to when it was on the boat.

C remains the same because the total mass of all the objects in the lake remains the same.

D remains the same because the rock will sink to the bottom of the lake and experience a normal contact force.

5 The diagram shows a box of mass 5.0 kg sliding down a frictionless slope inclined at 20° to the horizontal. A force *F* acts on the box at an angle of 30° to the horizontal such that the box moves down the slope at a constant speed.



What is the magnitude of the force *F*?

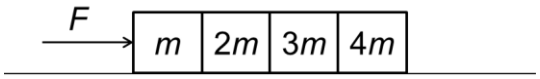
A 19 N

B 26 N

C 60 N

D 72 N

6 A horizontal force *F* acts on a system of masses *m*, 2*m*, 3*m* and 4*m*, on a smooth horizontal surface as shown in the diagram.



What is the contact force between the 2*m* and 3*m* masses in terms of *F*?

A 0.1 *F*

B 0.4 *F*

C 0.7 *F*

D 0.9 *F*

7 The rate of change of momentum experienced by a free falling ball when it hits the ground is equal to

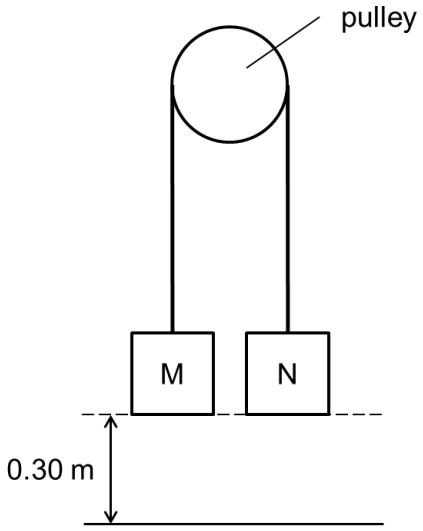
A its weight.

B the net force acting on it.

C the force exerted on it by the ground.

D the impulse on the ball due to the ground.

8 Masses M and N are connected by a string over a frictionless pulley. They are held stationary at 0.30 m above the ground as shown.



The masses are released and allowed to move.

What is the velocity of M on impact with the ground if masses M and N are 5.0 kg and 3.0 kg respectively?

A 1.2 m s^{-1} **B** 1.5 m s^{-1}

C 2.4 m s^{-1} **D** 3.6 m s^{-1}

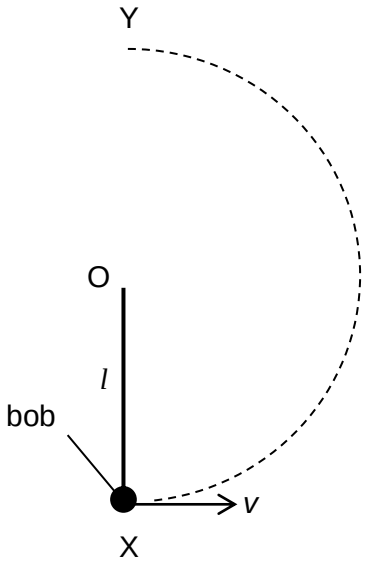
9 An electrical motor raises water 3.0 m up through a vertical pipe of circular cross-sectional area of 5.0 cm^2. The water is initially at rest at the bottom of the pipe and leaves the pipe at a constant speed of 1.5 m s^{-1}.

If the efficiency of the motor is 50%, what is the power supplied to the motor?
(density of water $= 1000$ kg m^{-3})

A 11 W **B** 22 W

C 23 W **D** 46 W

10 A bob is suspended from a point O by an inextensible string of length l. It is then projected horizontally from X, causing the bob to travel in a vertical circular path as shown in the diagram.



When the bob reaches Y, the string is just taut.

What is the speed v with which the bob is projected?

A $\sqrt{gl}$ **B** $\sqrt{2gl}$

C $\sqrt{4gl}$ **D** $\sqrt{5gl}$

11 A car rounds a bend of radius 80 m at a speed of $40\ \text{m s}^{-1}$.

What is the ratio of the friction on the race car to its weight?

A 0.051 **B** 0.49 **C** 2.0 **D** 20

12 A rock of mass 1.0 kg released from rest at a height of 100 m near the Earth's surface, takes a certain time to fall to the ground.

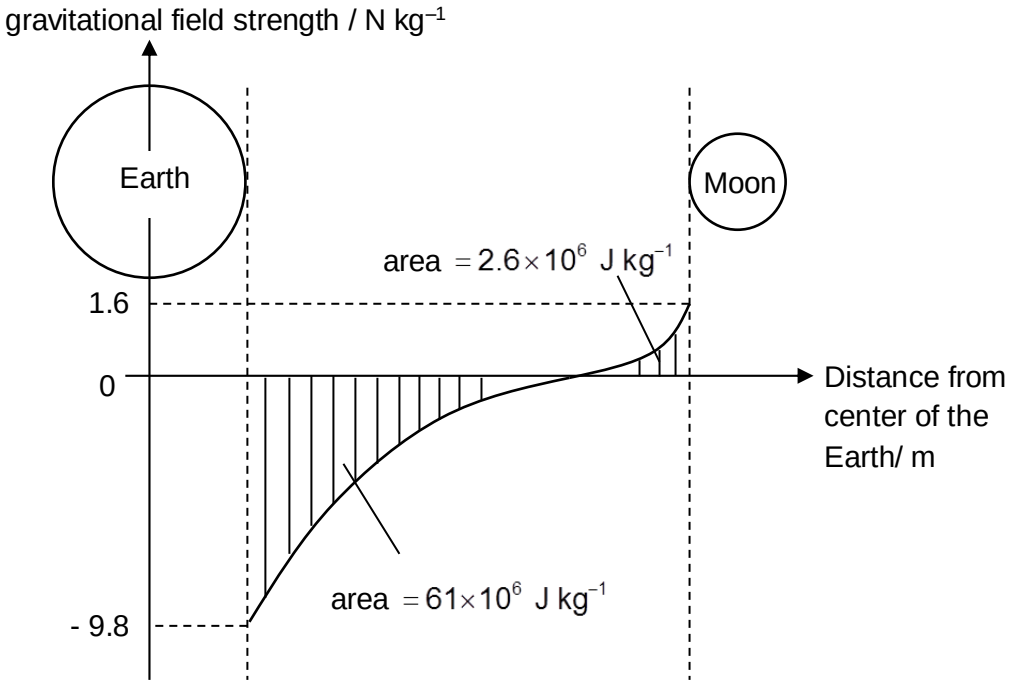
The same rock is released from rest from the same height on another planet with twice the radius and three times the density of Earth.

Given that the acceleration due to gravity near the Earth's surface is $9.81\ \text{m s}^{-2}$, how much faster will the rock take to fall on the other planet?

A 1.8 s **B** 2.7 s **C** 4.5 s **D** 6.5 s

13 The graph shows the variation with distance from the Earth of the gravitational field strength

between the surface of the Earth and the Moon. The magnitude of areas under the graph and the value of the gravitational field strength on the surface of the Earth and on the Moon are indicated.

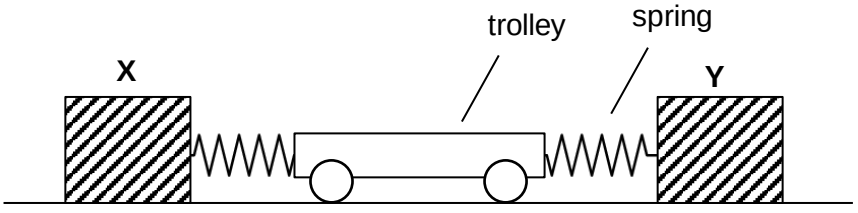


During a volcanic eruption on the Moon, a meteorite is projected towards the Earth.

What is the minimum speed with which the meteorite strikes the Earth?

A 186 m s^{-1} **B** 902 m s^{-1} **C** 2280 m s^{-1} **D** 11000 m s^{-1}

14 A trolley of mass 2.0 kg with free-rolling wheels is attached to two fixed supports X and Y by two light springs under tension as shown in the diagram below.

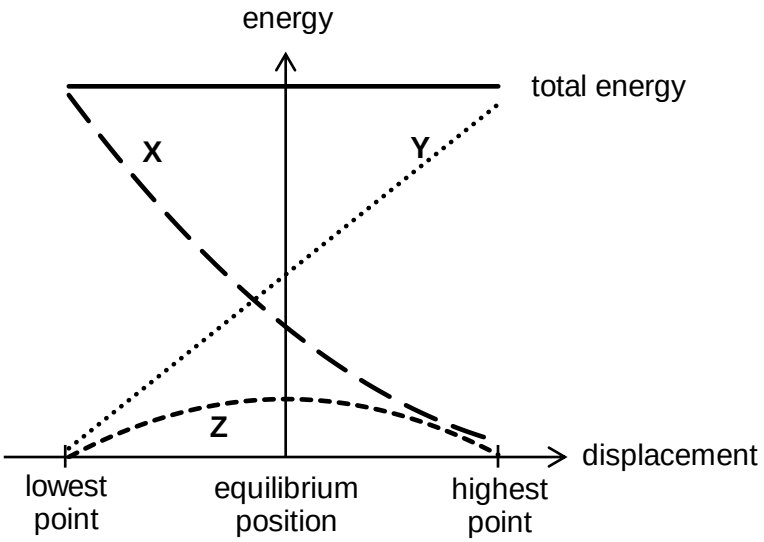


The trolley is displaced 5.0 cm towards Y by a force of 10 N and then released. The trolley undergoes simple harmonic motion.

What is the period of its oscillation?

A 0.063 s **B** 0.63 s **C** 1.6 s **D** 16 s

15 A mass attached to a spring is set into simple harmonic motion vertically. Interchange between kinetic energy, gravitational potential energy and elastic potential energy takes place throughout the oscillation. Three energy graphs X, Y and Z are plotted on the same axes below.



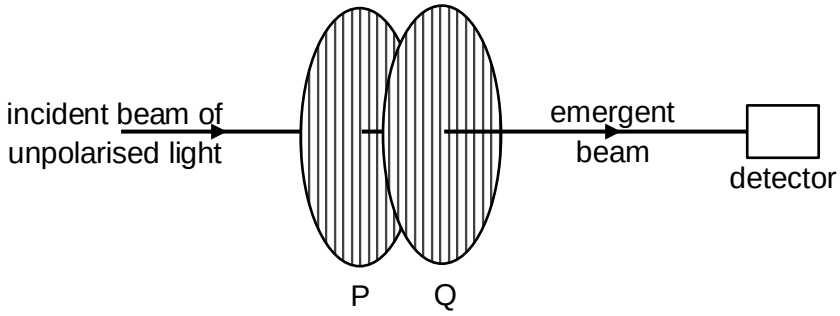
Which of the following combinations correctly identifies the graphs X, Y and Z?

	X	Y	Z
A	elastic potential energy	gravitational potential energy	kinetic energy
B	gravitational potential energy	kinetic energy	elastic potential energy
C	gravitational potential energy	elastic potential energy	kinetic energy
D	kinetic energy	elastic potential energy	gravitational potential energy

16 A transverse wave of wavelength λ is progressing along a horizontal rope from point X to point Y. If X and Y are $\frac{5\lambda}{4}$ apart, which of the following correctly describes the particle at point X at an instant when the particle at point Y is displaced downwards from equilibrium but moving upwards?

	Displacement of particle at X	**Movement of particle at X**
A	Downwards	Downwards
B	Downwards	Upwards
C	Upwards	Upwards
D	Upwards	Downwards

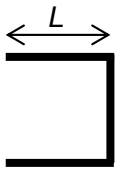
17 Two sheets of polaroid P and Q are placed such that their planes of polarisation are parallel as shown. A beam of unpolarised light passes through them and is incident on the detector. The intensity detected is I.



Which of the following is a possible angle through which Q can be rotated such that the intensity detected is reduced by 30%?

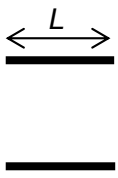
A 213° **B** 226° **C** 237° **D** 253°

18 A sound wave resonates at its fundamental frequency in the following pipe of length L.

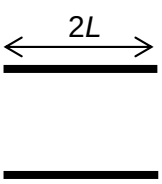


In which other pipe would a sound wave of half the frequency resonate in?

A



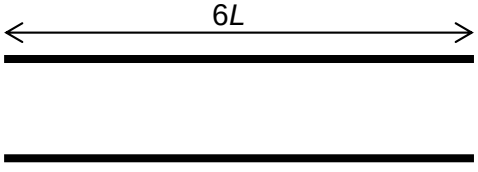
B



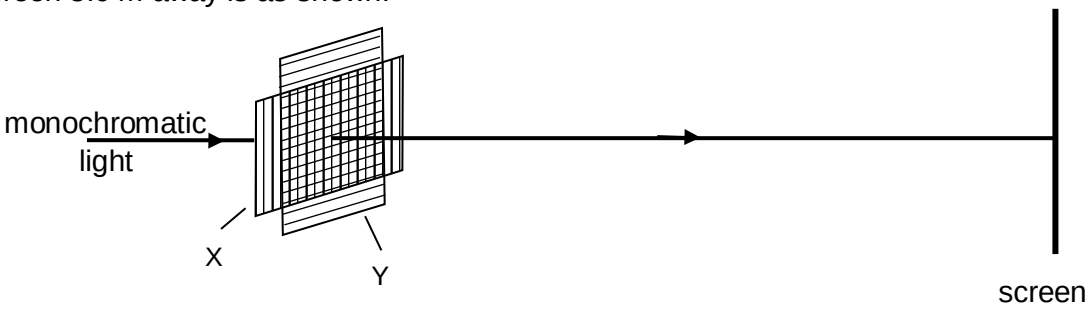
C

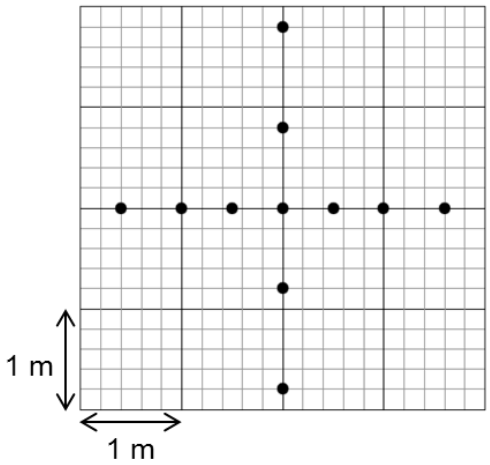


D



19 A beam of monochromatic light of wavelength 450 nm passes through 2 diffraction gratings X and Y that are positioned perpendicular to one another. Part of the interference pattern on a screen 3.6 m away is as shown.





interference pattern on the screen

If the distance between the two gratings is negligible, what is the approximate number of lines per metre for grating X?

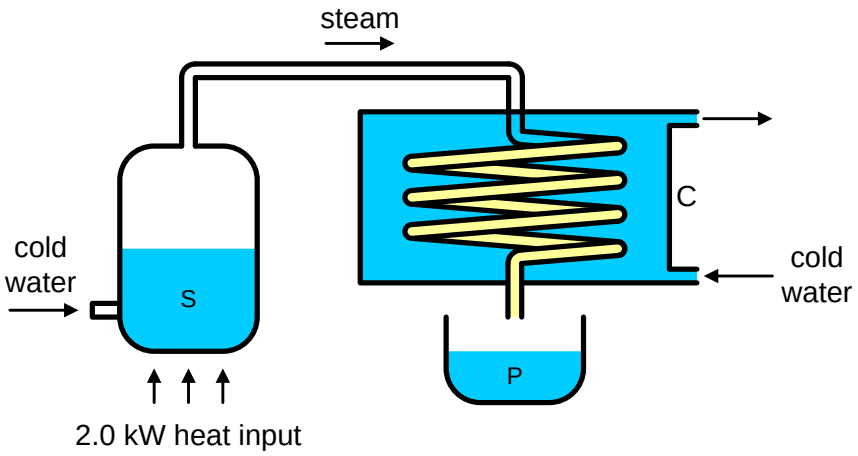
A 2×10^5 lines per metre

B 3×10^5 lines per metre

C 4×10^5 lines per metre

D 5×10^5 lines per metre

20 A set up used to provide a supply of pure distilled water from river water is as shown.



Cold water enters a container S at 20 °C and is vaporised. The steam at 100 °C is condensed by cold water circulating in the condenser C and the pure water is collected at P.

Given that the specific latent heat of vaporisation of water is 2.2 MJ kg^{-1} and the specific heat capacity of water is 4200 J kg^{-1} K^{-1}, what is the rate of production of distilled water?
Ignore all heat losses.

A 7.6×10^{-4} kg **B** 7.9×10^{-4} kg **C** 9.1×10^{-4} kg **D** 6.0×10^{-3} kg

21 The average kinetic energy of the molecules of an ideal gas in a closed, rigid container is increased by a factor of 4.

Which of the following accurately describes the change in the pressure of the gas?

A It remains the same.

B It increases by a factor of 2.

C It increases by a factor of 4.

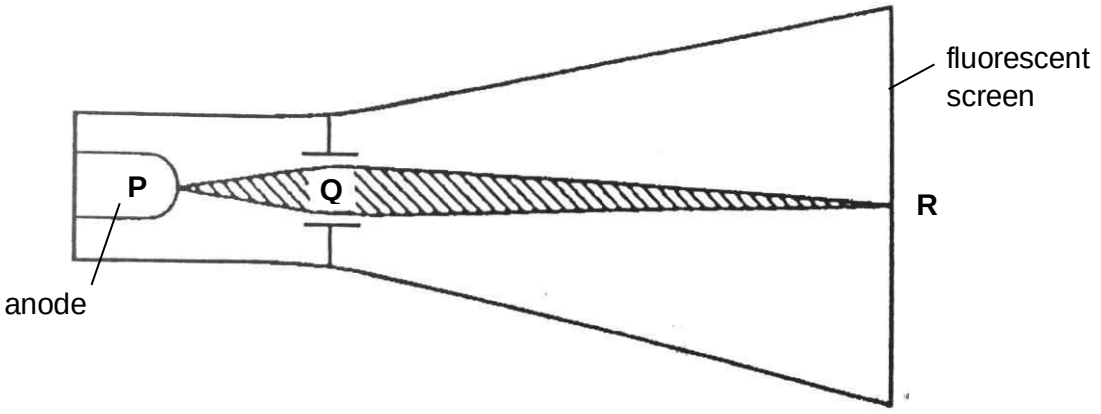
D It increases by a factor of 8.

22 Two identical vessels containing the same ideal gas, are connected by an open tube of negligible volume. Initially both vessels are at temperature T and pressure P. The temperature of one vessel is raised to $2T$, while the other is maintained at T.

The new equilibrium pressure is

A $\frac{2}{3}P$ **B** $\frac{4}{3}P$ **C** $\frac{3}{2}P$ **D** $\frac{7}{4}P$

23 The diagram shows a cathode ray tube in an oscilloscope. The shaded area represents a section through the electron beam which is generated near the anode P, deflected and accelerated at Q and focused at the fluorescent screen R. The tube contains no gas.



How does the electric current of the beam vary along PQR?

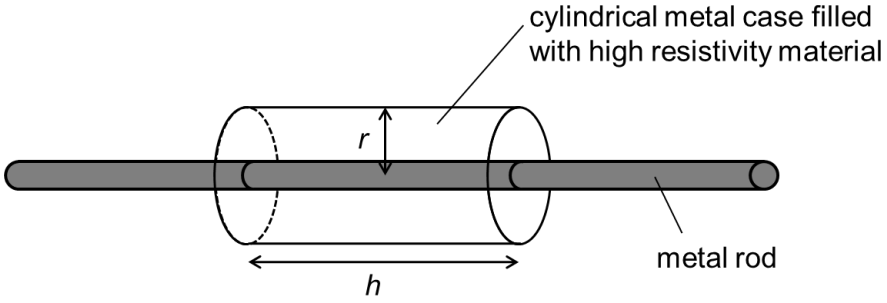
A It has the same value at P, Q and R.

B It decreases from P to Q, and then further decease from Q to R.

C It decreases from P to Q, then increase to reach the same value at R as at P.

D It increases from P to Q, then decrease to reach the same value at R as at P.

24 In the model of a coaxial cable, the space between a metal rod and the cylindrical metal case is filled with a conducting material of high resistivity. A segment of the cylindrical metal case has length h and radius r.



The resistance between the case and the metal rod is

A proportional to h/r^2 .

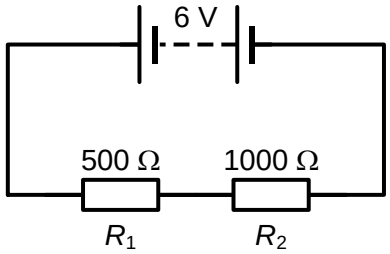
B proportional to h/r .

C inversely proportional to r.

D inversely proportional to h.

25 The diagram shows a 6 V battery, with negligible internal resistance, connected in series to two resistors R_1 and R_2.

R_1 has a resistance of 500 Ω and R_2 has a resistance of 1000 Ω.



A third resistor with a resistance of 500 Ω is placed in parallel across R_2.

Which statement about the new circuit is correct?

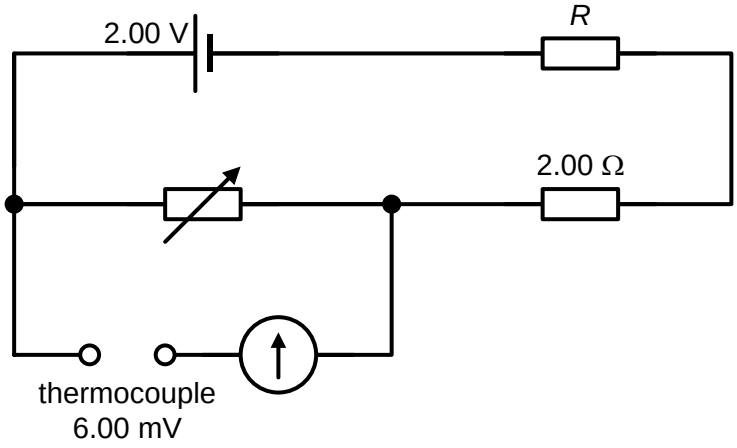
A The current in R_2 is larger than before.

B The current through the battery is smaller than before.

C The potential difference across R_1 is larger than before.

D The potential difference across R_2 is now greater than the potential difference across R_1.

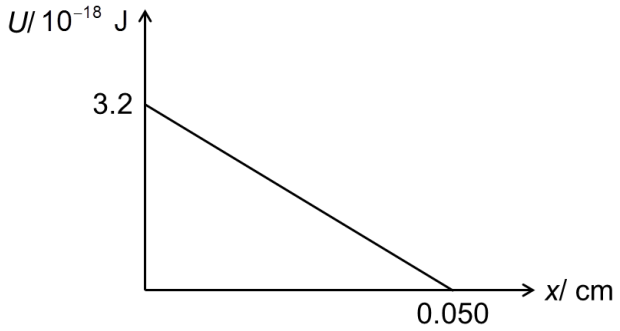
26 The diagram shows a circuit for measuring a small e.m.f. of 6.00 mV produced by a thermocouple. There is zero current in the galvanometer when the variable resistor is set to 3.00 Ω.



What is the value of the resistance *R*?

A 667 Ω **B** 995 Ω **C** 1000 Ω **D** 1662 Ω

27 Two charged parallel plates, separated by a distance of 0.050 cm, produce a uniform electric field between them. The potential energy U of a proton in the field varies with displacement x from one of the plates as shown in the graph.



What is the magnitude of the acceleration on the proton?

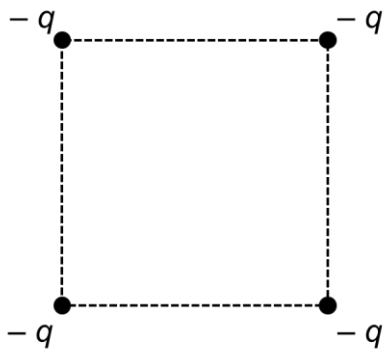
A 3.8×10^{12} m s^{-2} **B** 7.0×10^{15} m s^{-2}

C 2.4×10^{31} m s^{-2} **D** 4.4×10^{34} m s^{-2}

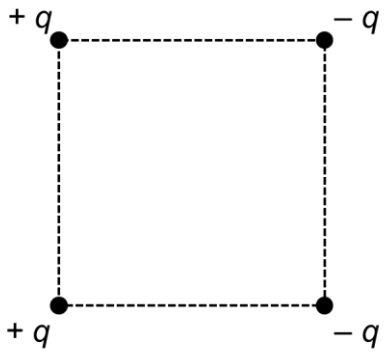
28 Point charges, each of magnitude q, are arranged at the corners of a square.

For which arrangement will the magnitude of the resultant electric field strength at the centre of the square be the largest?

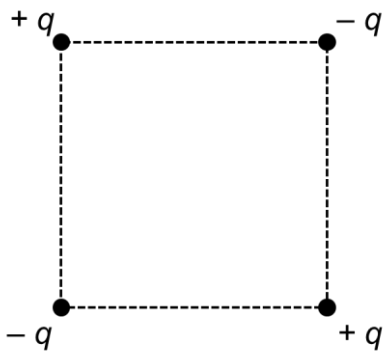
A



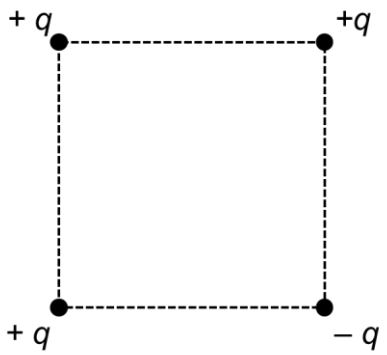
B



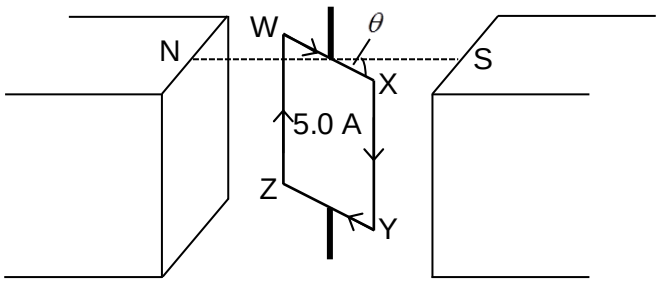
C



D



29 A square coil WXYZ has 20 turns and sides 0.20 m. The coil carries a current of 5.0 A and is placed in a uniform magnetic field of flux density 0.80 T.



What is the torque acting on the coil when side WX makes an angle θ of 30° with the magnetic field?

A 1.4 N m

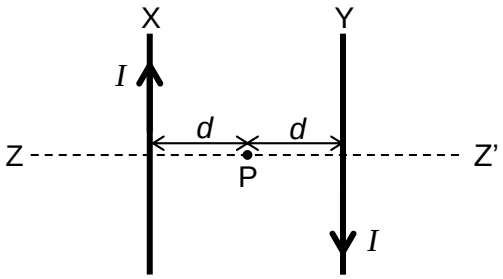
B 1.6 N m

C 2.8 N m

D 3.2 N m

30 Two infinitely long straight conductors X and Y are placed parallel to each other. Each conductor carries a current I. Point P is equidistant from either conductor.

X is fixed while Y is rotated about the axis ZZ' until it is perpendicular to X and its current is out of the plane of the paper.



Which of the following statements describing what happens during the rotation is incorrect?

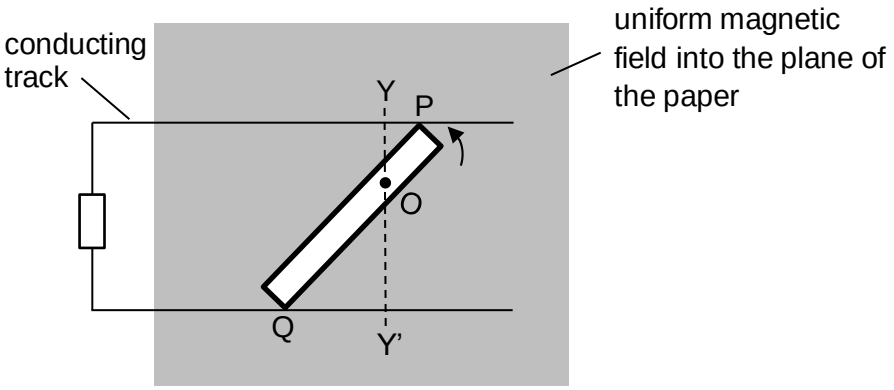
A X experiences a force to the left that decreases to zero.

B The forces on X and Y are always equal in magnitude and opposite in direction.

C The resultant magnetic flux density at P decreases to a value that is $\sqrt{2}$ times the flux density due to each wire at P.

D If Y is rotated about the axis ZZ' until it is perpendicular to X but its current is into the plane of the paper, the effect on the magnitude of the resultant magnetic flux density at P is opposite.

31 A rod PQ is placed in a uniform magnetic field acting perpendicularly into the plane of the paper. The rod rotates about a point O in the direction shown until it is vertical along YY'.



What is the direction(s) of the current(s) in the rod PQ during this rotation?

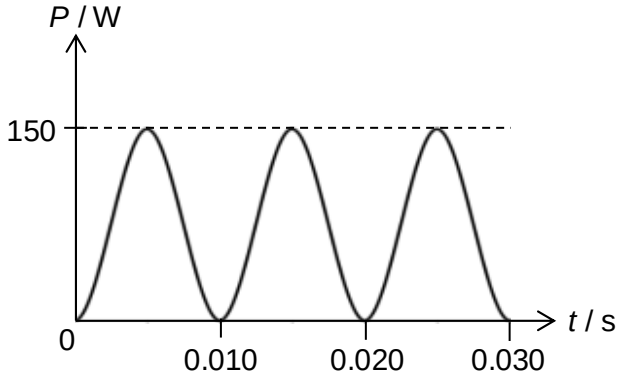
A No current will flow

B P to Q

C Q to P

D O to P and O to Q

32 The graph shows the variation with time *t* of the power *P* dissipated in a resistor of resistance 6.0 Ω when it is connected to an alternating supply.



Which equation represents the sinusoidal alternating current through the resistor?

A $I = 5.0\sin 100\pi t$

B $I = 5.0\sin 200\pi t$

C $I = 25\sin 100\pi t$

D $I = 25\sin 300\pi t$

33 Which of the following statements about a transformer is correct?

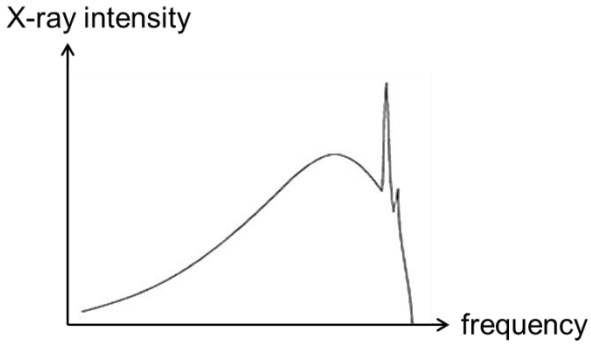
A The soft iron core is laminated to reduce hysteresis loss.

B The electrical power loss in the primary and secondary coils can be reduced by using thicker wires.

C The turns ratio $\frac{N_S}{N_P}$ is always equal to the ratio of the current in the primary coil to the current in the secondary coil.

D The peak value of the induced e.m.f. in the secondary coil can be increased by making the part of the iron core that is through the secondary coil thicker than the part through the primary coil.

34 X-rays are produced when electrons that are accelerated through a potential difference strike a metal target in an X-ray tube. The X-ray spectrum emitted from an X-ray tube is shown in the diagram below.



If the accelerating potential difference is increased, which one of the following combinations represents a possible change in the maximum frequency of the X-ray spectrum as well as the frequencies and intensities of the peaks?

	maximum frequency	frequencies of peaks	intensities of peaks
A	increase	remain the same	increase
B	decrease	increase	remain the same
C	remain the same	remain the same	decrease
D	increase	decrease	increase

35 An electron moves with a constant velocity of 1.5×10^{6} m s^{-1}. If its momentum is measured to a precision of 0.2%, what is the uncertainty associated with its position?

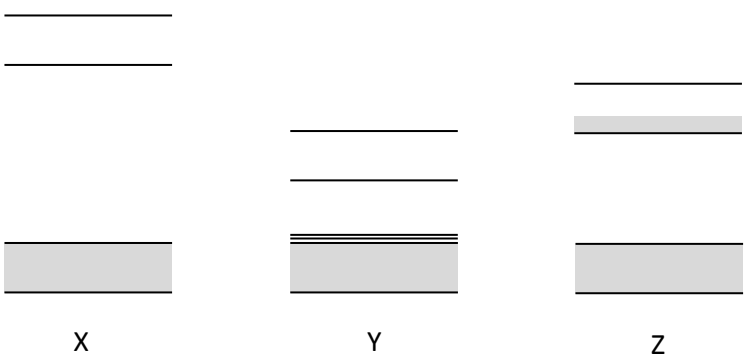
A 1.9×10^{-8} m

B 3.9×10^{-8} m

C 1.2×10^{-10} m

D 1.9×10^{-10} m

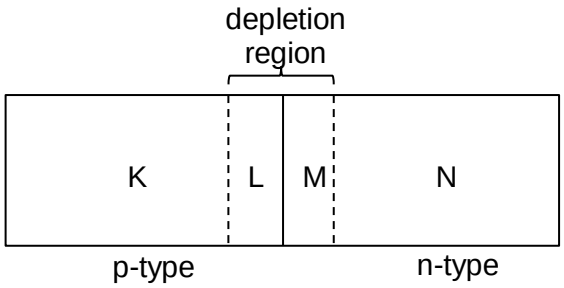
36 The diagram shows the energy bands for three types of materials, X, Y and Z. The shaded areas represent occupied energy levels.



Which of the following correctly identifies the materials?

	X	Y	Z
A	pure semiconductor	p-type semiconductor	metal
B	insulator	p-type semiconductor	metal
C	insulator	metal	n-type semiconductor
D	insulator	n-type semiconductor	metal

37 The diagram shows a p-n junction of a diode divided into four regions K, L, M and N.



Which of the following statements is correct?

A Under forward bias condition, holes flow from K to N, but electrons from N to K.

B Under forward bias condition, regions L and M become wider and this reduces the resistance of the diode.

C Group III atoms can be found in region N.

D Region L is an electrically neutral region formed by the recombination of electrons with Group III atoms.

38 In Rutherford's α-particle scattering experiment, the collisions between α-particles and electrons can be neglected because

A there are very few such collisions due to the high speed of the electrons.

B the loss in the kinetic energy of the α-particles during such collisions is negligible.

C the collisions are random and do not result in any net effect on the motion of the α-particles.

D the mass of the electron is too small to produce any significant effect on the motion of the α-particles when they collide.

39 A radioactive source consists of a mixture of two isotopes P and Q.

P has a half-life of 60 minutes and Q has a half-life of 30 minutes. The initial count rate recorded by a suitable counter is 800 min^{-1}. After 120 minutes the counter registers a count rate of 80 min^{-1}.

What was the initial count rate of P?

A 160 min^{-1} **B** 240 min^{-1}

C 480 min^{-1} **D** 640 min^{-1}

40 Uranium-238 decays by a series of alpha, beta and gamma decays into a final stable nuclide.

Which of the following is the final stable nuclide of the series?

A ^{205}Tl **B** ^{206}Pb

C ^{207}Pb **D** ^{208}Pb

End of Paper

Centre Number	Index Number	Name	Class
3016			

RAFFLES INSTITUTION
2016 Preliminary Examination

PHYSICS **9646/03**
Higher 2

20 September 2016
Paper 3 Longer Structured Questions **2 hours**

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, 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 staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions and **circle the question number** on the cover page.

You are advised to spend about one hour on each section.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section A.**

For Examiner's Use		
Section A	1	/ 10
	2	/ 10
	3	/ 10
	4	/ 10
Section B (circle 2 questions)	5	/ 20
	6	/ 20
	7	/ 20
Deduction		
Total		/ 80

This booklet consists of **12** printed pages including the cover page.

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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	v	=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

Section A

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows block A of mass 1.5 kg held against a massless spring with a force *F*. The spring is compressed by 2.0 cm.

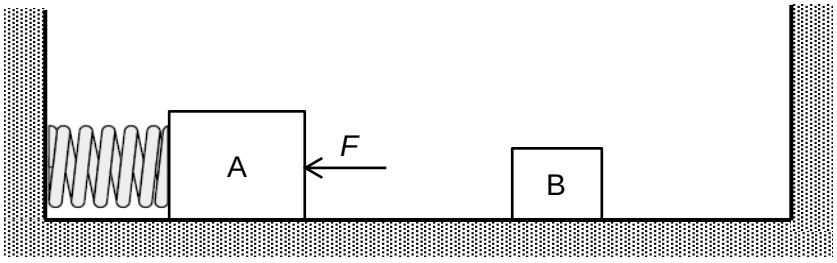


Fig. 1.1

Force *F* is then removed and the spring returns to its natural length. Block A loses contact with the spring with a speed of 0.50 m s^{-1} and approaches a stationary block B of mass 0.50 kg as shown in Fig. 1.2.

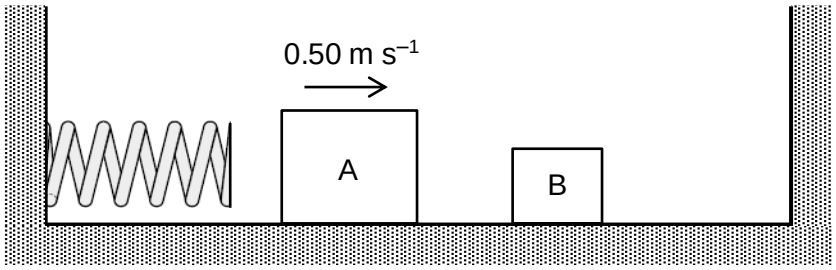


Fig. 1.2

Ignore all resistive forces.

(a) Determine the force constant *k* of the spring.

k = ... N m^{-1} [2]

(b) Block A collides head-on with block B. Assuming the collision is elastic, determine the final velocity of B.

final velocity of B = ... m s^{-1} [3]

(c) Fig 1.3 shows the variation with time of the force acting on block A during the collision with block B.

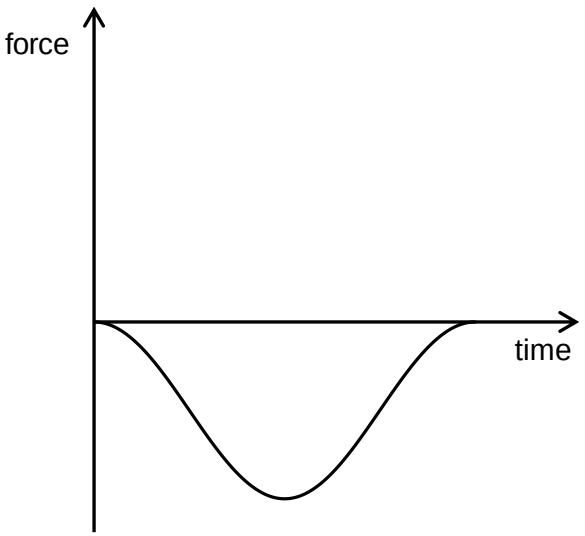


Fig. 1.3

(i) Sketch on Fig. 1.3, the corresponding graph of how the force on B varies with time during the duration of the collision.

[1]

(ii) Explain how your graph is consistent with the principle of conservation of momentum

.....

.....

.....

..... [2]

(d) Block B hits the opposite wall elastically, rebounds and collides with block A again. State with reason whether the new compression of the spring will be more or less than 2.0 cm.

.....

.....

.....

..... [2]

2 **(a)** One condition for a satellite to be geostationary is that it must have an orbital period of one day. State 2 other conditions that must be satisfied in order for a satellite to be geostationary.

1. .....

.....

2. .....

..... [2]

(b) A geostationary satellite of mass 670 kg orbits around the Earth. The mass of the Earth is 5.99×10^{24} kg and its radius is 6.37×10^{6} m.

(i) Show that the orbital speed of the satellite is 3070 m s^{-1}.

[2]

(ii) The difference in gravitational potential between points on the surface of Earth and points along the orbit of the satellite is 7.19 MJ kg^{-1}.

Neglecting the effects due to the Earth's rotation, determine the energy input required to launch this geostationary satellite from rest from the surface of Earth into its orbit.

energy = ... J [2]

(c) For any satellite of mass *m* orbiting with radius *R* around a planet of mass *M*, its kinetic energy *K*, gravitational potential energy *U* and total energy *T* depend on one another.

(i) By deriving an appropriate expression for *K*, show that *K* and *U* are related by

$$2K + U = 0$$

[2]

(ii) Fig. 2.1 shows the variation with distance from the centre of a planet of the kinetic energy *K* of a satellite. *R* is the radius of the planet.

Sketch clearly, on the same axes, the corresponding graphs of gravitational potential energy and total energy of the satellite. Label your graphs *U* and *T* respectively.

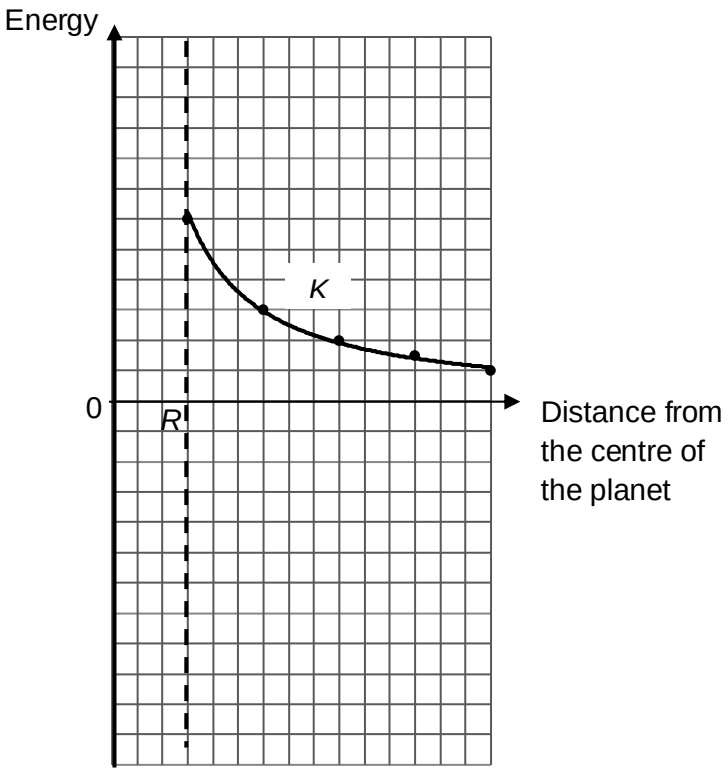


Fig. 2.1

[2]

3 **(a)** Define *electric field strength* at a point.

.....

.....

[1]

(b) Fig. 3.1 shows a simplified, full scale cross sectional view of an electrostatic lens for focusing charged particles. The set-up consists of two charged cylinders. A beam of high speed electrons passes through the non-uniform electric field along the axis of the cylinders, from left to right. The dotted lines are equipotential lines. X, Y and Z are points along the same horizontal line.

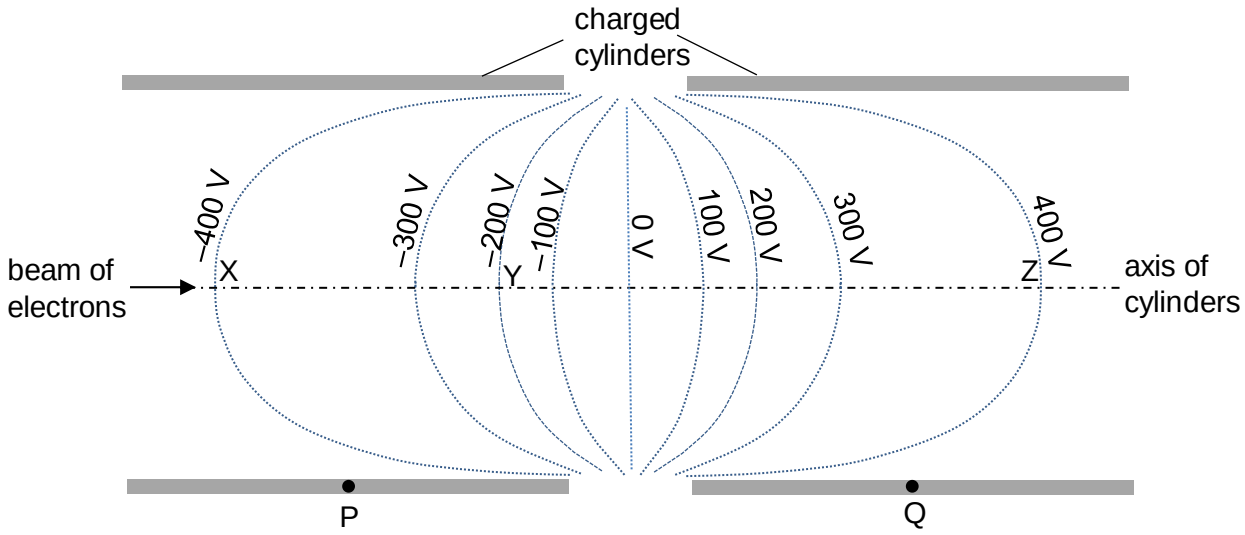


Fig. 3.1 (full scale)

(i) On Fig. 3.1, draw a possible electric field line in the region below the horizontal line XYZ from point P to point Q. [2]

(ii) Calculate

1. the speed of an electron at Z given that it enters at X with a speed of 8.0×10^5 m s^{-1},

speed at point Z = ... m s^{-1} [2]

2. the approximate value of the electric field strength at Y,

electric field strength at Y = ... V m^{-1} [2]

3. the electric force experienced by an electron at point Y.

electric force at Y = ... N [1]

(c) Fig. 3.2 shows the cross sectional view of another type of electrostatic lens made up of three charged cylinders where the cylinder in the middle is at a potential of –100 V and the cylinders on either side of it are each at a potential of –10 V. The charged cylinders are separated by a small gap. The lines shown are the electric field lines.

An ion beam enters the lens system from the left and is focused to a point on the right-hand side of the system as shown in Fig. 3.2.

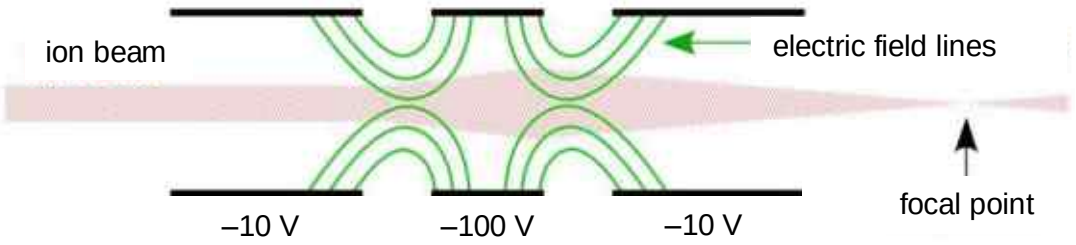


Fig. 3.2

State, with a reason, whether the kinetic energy of an ion in the beam increases, decreases or remains the same after passing through the electrostatic lens.

.....

.....

..... [2]

4 **(a)** Two charged particles X and Y travelling in the same direction, each with velocity v, enter a uniform magnetic field of flux density B in a vacuum. Particles X and Y have the same mass m but different charges q_X and q_Y respectively.

The paths of particles X and Y in the magnetic field are shown in Fig. 4.1. The radius of the semi-circular path of particle Y is double that of particle X.

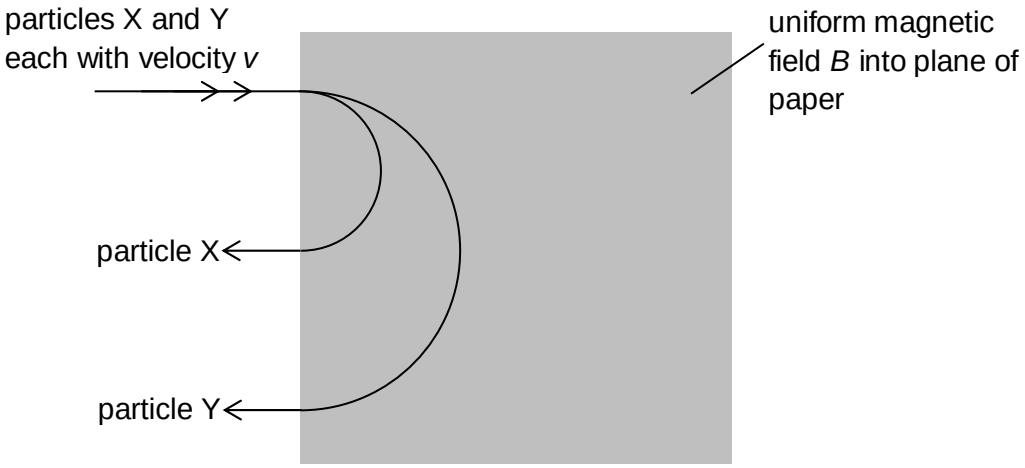


Fig. 4.1

(i) Explain clearly why the paths of the charged particles are circular in the magnetic field.

.....

.....

.....

..... [2]

(ii) State if the charge of the particles is positive or negative.

..... [1]

(iii) Determine the ratio $\frac{q_Y}{q_X}$.

$\frac{q_Y}{q_X}$ = ... [2]

(b) Particle X with velocity *v* now enters another uniform magnetic field region having the same flux density *B* as before but with uncharged gas particles throughout. It moves in a spiral path in the magnetic field as shown in Fig. 4.2.

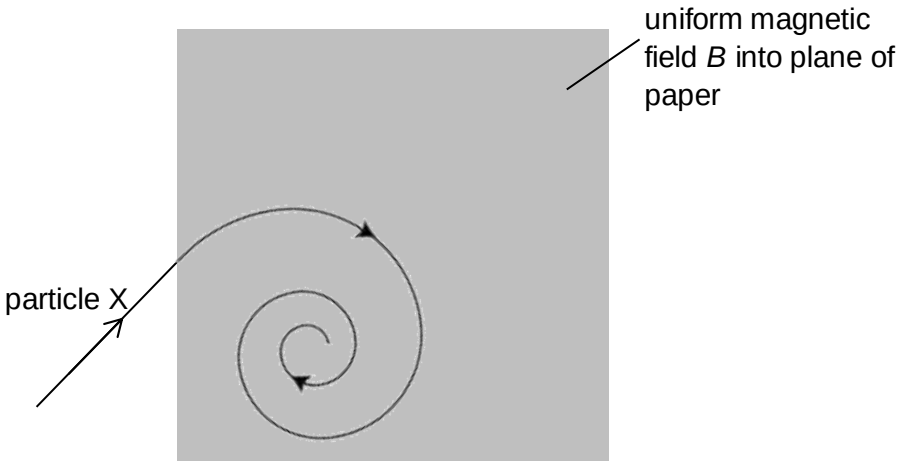


Fig. 4.2

(i) Give an explanation for the spiral path of particle X. Show any relevant equations used in your explanation.

.....

.....

.....

..... [2]

(ii) **1.** Deduce an expression for the time *T* taken for one revolution of the spiral path in terms of *m*, q_X and *B*.

T = ... [2]

2. The tau particle is an elementary particle that has the same charge as an electron but has a mass that is 3000 times that of an electron. It has a mean lifetime of 2.9×10^{-13} s. State with a reason if particle X could be a tau particle if B = 1.0 T.

.....

..... [1]

End of Section A

Centre Number	Index Number	Name	Class
3016			

RAFFLES INSTITUTION
2016 Preliminary Examination

PHYSICS **9646/03**
Higher 2

20 September 2016
Paper 3 Longer Structured Questions **2 hours**

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces provided at the top of this page.
Write in dark blue or black pen.
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Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions and **circle the question number** on the cover page.

You are advised to spend about one hour on each section.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section B.**

For Examiner's Use		
Section B (circle 2 questions)	**5**	/ 20
	6	/ 20
	7	/ 20
Deduction		

This booklet consists of **14** printed pages including the cover page.

Section B

Answer **two** questions from this Section in the spaces provided.

5 A four-stroke engine is an internal combustion engine commonly used in automobiles. Fig. 5.1 shows the cross-sectional view of the engine during the intake stroke, compression stroke, ignition phase, expansion stroke and exhaust stroke.

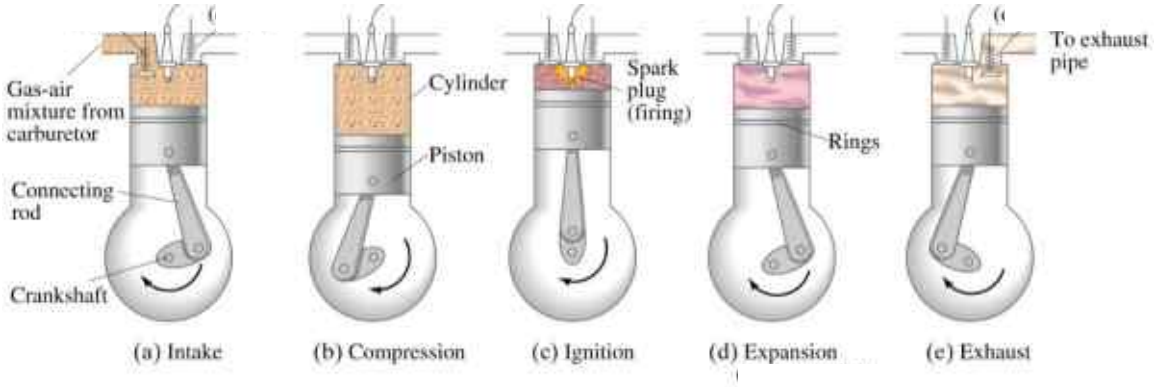


Fig. 5.1

The operation of the four-stroke engine is commonly based on the Otto cycle which consists of the following six processes:

Process	Name	Description
0	**Intake stroke**	Petrol-air mixture (of a constant ratio of 1:15) is drawn into the combustion chamber at constant pressure.
I	**Compression stroke**	The petrol-air mixture undergoes a fast (adiabatic) compression from V_1 to V_2.
II	**Ignition phase**	At maximum compression, the petrol-air mixture is ignited by the firing spark plug which releases heat at constant volume.
III	**Expansion stroke**	The high-pressure exhaust-air mixture undergoes a fast (adiabatic) expansion from V_2 to V_1.
IV	**Cooling phase**	When the piston is at its lowest position, heat is expelled to the surrounding at constant volume.
V	**Exhaust stroke**	The exhaust-air mixture is expelled out of the combustion chamber at constant pressure.

In one cycle of a four-stroke engine, the intake stroke and compression stroke occur in one revolution of the engine crankshaft while the expansion stroke and the exhaust stroke occur in the next revolution. Hence each complete cycle requires two revolutions of the crankshaft to complete.

Assume that the mixture is ideal.

(a) On Fig. 5.2, sketch and label the variation with volume V of the pressure p of the mixture during processes I, II, III and IV.

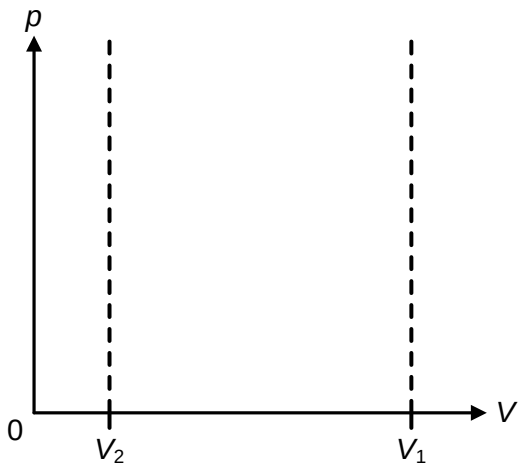


Fig. 5.2

[2]

(b) At the beginning of the compression stroke (process I), the petrol-air mixture in the combustion chamber has a volume $V_1 = 600\ \text{cm}^3$, pressure of 1.00×10^5 Pa and temperature of 25°C.

Calculate the mass m of the petrol-air mixture in the cylinder, given that the molar mass of the petrol-air mixture is approximately $0.0288\ \text{kg mol}^{-1}$.

m = ... kg [3]

(c) For the compression stroke (process I) and expansion stroke (process III), the relationship between the temperature T and volume V of the petrol-air mixture is

$$TV^{0.4} = k,$$

where k is a constant.

(i) If the compression ratio $V_1/V_2 = 7.00$, calculate the temperature T_2 of the petrol-air mixture at the end of the compression stroke (process I).

T_2 = ... K [2]

(ii) A particular brand of fuel has an auto-ignition temperature of 600 K, explain why this fuel may result in damage to the components of the engine.

.....

.....

.....

..... [2]

(d) The amount of heat released by the ignition of the petrol-air mixture (process II) is 600 J. Given that the specific heat capacity (at constant volume) of the petrol-air mixture is 722 J kg^{-1} K^{-1}, calculate the temperature T_3 of the petrol-air mixture after ignition.

T_3 = K [2]

(e) The internal energy of the petrol-gas (or exhaust-air) mixture is given by

$$U = \frac{5}{2}nRT ,$$

where n is the number of moles.

Calculate

(i) the work done on the petrol-air mixture, $W_{\text{I, on mixture}}$ during the compression stroke (process I).

$W_{\text{I, on mixture}}$ = ... J [3]

(ii) the work done by the exhaust-air mixture, $W_{\text{III, by mixture}}$ during the expansion stroke (process III), given that the temperature T_4 of the mixture at the end of the expansion stroke is 845 K.

$W_{\text{III, by mixture}}$ = J [2]

(f) The power of an engine is defined as the rate of net work done by the engine i.e. the petrol/exhaust-air mixture.

Calculate the power of this engine operating at 3000 rev min^{-1}.

power = ... W [2]

(g) Explain why such an engine generates more power on a cold day given that air is denser at lower temperature.

.....

.....

.....

..... [2]

6 **(a)** Define the following quantities and state the SI unit for each.

(i) magnetic flux density

.....

.....

.....

..... [2]

(ii) magnetic flux

.....

.....

.....

..... [2]

(b) The set-up shown in Fig. 6.1 may be used to generate electricity. A stationary coil of wire with a large number of turns is placed mid-way between two rotating ceramic discs P and Q connected by an axle.

Each of the discs contains six embedded magnets that are uniformly spaced along the circumference of the disc. The north and south poles of the magnets on each disc are alternated. At the start, a magnet on each of the discs is in line with the coil of wire. The two discs are then rotated at a constant rate of 50 revolutions per second.

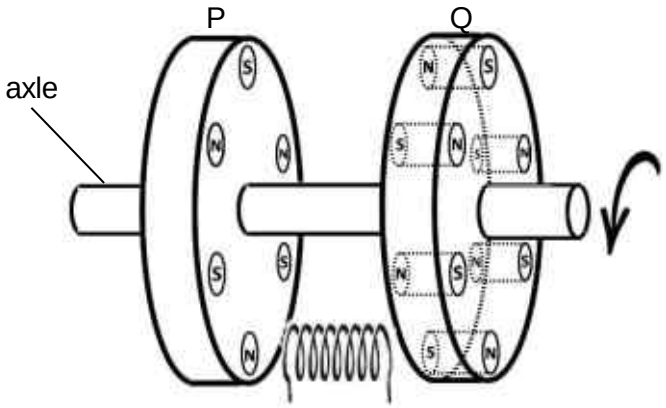


Fig. 6.1

(i) Explain why an e.m.f. is generated in the coil.

.....

.....

..... [2]

.....

(ii) Fig. 6.2 shows the variation with time t of the e.m.f. E generated in the coil. E_0 is the value of the peak e.m.f. and T is the period of revolution.

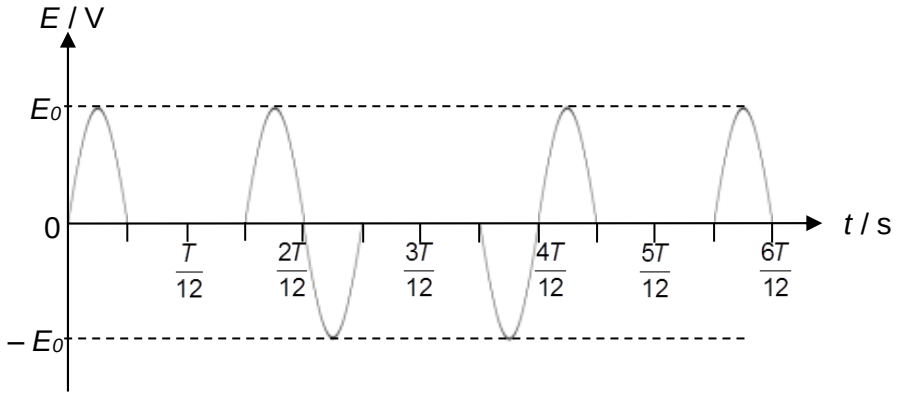


Fig. 6.2

1. Complete the graph of magnetic flux linkage Φ against time t in Fig. 6.3 from $t = 0$ to $t = \frac{6T}{12}$.

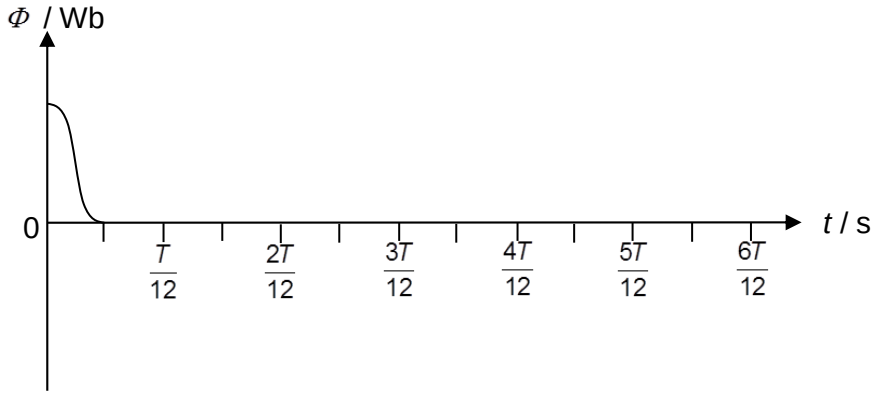


Fig. 6.3

[1]

2. Account for the Φ–t graph in Fig. 6.3 and state how the E–t graph in Fig. 6.2 may be obtained from it.

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

(iii) State two ways by which the value of the peak e.m.f. E_0 generated in the coil may be increased if the number of turns of the coil is fixed.

1. .....

2. ..... [2]

(iv) The e.m.f. E generated in the coil in Fig. 6.2, whose curves are approximately sinusoidal in shape, is connected to the input of an ideal transformer. The value of the peak e.m.f. E_0 is 100 V.

The transformer has 40 turns on its primary coil and 800 turns on its secondary coil. The output from the transformer is connected to an ideal diode and a resistor of 200 Ω as shown in Fig. 6.4.

Assume that the primary and secondary voltages of the transformer are in phase.

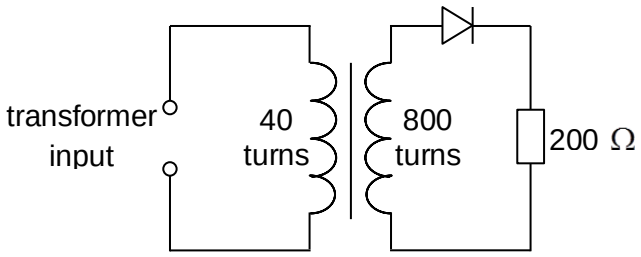


Fig. 6.4

1. Determine the period T of the rotating discs.

T = ... s [1]

2. Calculate the peak output voltage of the transformer.

peak output voltage = ... V [1]

3. In Fig. 6.5, sketch the variation with time t of the potential difference V_R across the resistor from $t = 0$ to $t = \frac{6T}{12}$.

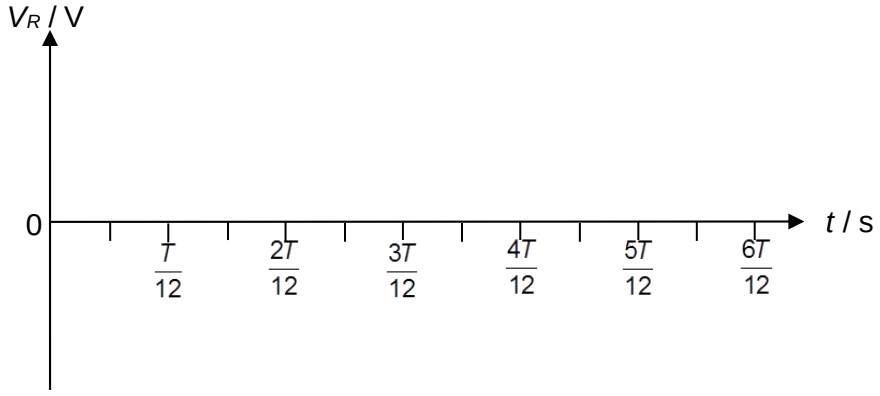


Fig. 6.5

[1]

4. Show that the r.m.s. value of the potential difference across the resistor is 707 V.

[2]

5. Calculate the mean power dissipated in the resistor.

mean power = ... W [1]

(v) Explain why an external torque has to be constantly applied to discs P and Q to keep it rotating at a constant rate when the transformer is connected to the coil.

.....

.....

.....

.....

.....

.....

..... [2]

7 **(a)** The Sun is a star that comprises mainly of hydrogen nuclei (protons). It derives its large radiative power from nuclear fusion. The nuclear reactions responsible for energy generation in the Sun, collectively known as the proton-proton chain reactions, are listed as follows:

I. $^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{1}e +$ other radiations

II. $^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \text{energy}$

III. $^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + n\ {}^{A}_{1}\mathrm{Y} +$ energy

where $^{0}_{1}e$ denotes a positron. A positron is a particle with the same mass as an electron but having a charge of $+e$.

(i) For reaction III, identify the number n and name the particle Y

n = ... [1]

Y = ... [1]

(ii) Deuterons ($^{2}_{1}\mathrm{H}$) are produced in reaction I. Suggest a reason why reactions II and III are observed in the formation of helium-4 instead of the following one:

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + \text{energy}$$

.....

.....

..... [1]

(iii) Reactions I to III can be combined into one overall reaction:

$$4\,{}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{0}_{1}e + \text{energy}$$

It is given that

mass of proton:	1.007276 *u*
mass of alpha particle:	4.001506 *u*
mass of positron:	0.000585 *u*

where *u* is the atomic mass unit.

Calculate the amount of energy released in one such reaction.

energy = ... J [3]

(b) The Earth is at a distance of 1.5×10^{11} m away from the Sun. The maximum intensity of sunlight at the Earth's surface can reach as high as 1400 W m^{-2} at normal incidence.

(i) Use the above information to determine the amount of energy generated by the Sun in one second.

energy generated per second = ... W [2]

(ii) Hence, determine

1. the number of nuclear reactions described in **(a)(iii)** that occur in the Sun every second.

reactions per second = ... [1]

2. the time taken for the Sun to be depleted of hydrogen, assuming that the total mass of the hydrogen in the Sun is now 2.0×10^{30} kg and the rate of nuclear reactions remain constant until all the hydrogen is depleted.

time taken = ... s [2]

(c) Apart from electromagnetic radiation, the Sun also showers the Earth with a large number of protons with very high kinetic energy. When these protons collide with the atoms in the atmosphere, they produce neutrons which in turn react with nitrogen in the air to form carbon-14:

$$^{14}_{7}\mathrm{N} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H}$$

Carbon-14 is radioactive with a half-life of 5730 years. In atmospheric carbon dioxide, about 1 out of 10^{12} carbon atoms are carbon-14. During photosynthesis, green plants take in carbon dioxide and convert them into carbon compounds. Because the mixing of carbon-14 with carbon-12 is efficient, all living things have the same ratio of carbon-14 to carbon-12.

(i) Define *half-life*.

.....

..... [1]

(ii) Carbon-14 decays spontaneously into nitrogen-14. Write down the equation for this reaction.

[1]

(iii) The radioactivity of a 33.3 g piece of charcoal, assumed to be pure carbon, found from the remains of an ancient campfire is measured to be 0.4 counts per second. This value was derived from a measurement of 240 decays over 10 minutes.

1. Explain why, for this piece of charcoal, it is a good experimental practice to measure the number of decays over 10 minutes rather than 1 minute or 1 second.

.....

.....

.....

[2]

2. In living wood, 1 out of 10^{12} carbon atoms are carbon-14.

Show that the number of carbon atoms in this piece of charcoal is about 1.67×10^{24}.

Hence estimate the age of this piece of charcoal.

age = ... years [5]

End of Section B

2016 Raffles Institution Preliminary Examination

H2 Physics Paper 1

1	**A**	6	**C**	11	**C**	16	**C**	21	**C**	26	**B**	31	**C**	36	**B**
2	**C**	7	**B**	12	**B**	17	**A**	22	**B**	27	**A**	32	**A**	37	**A**
3	**D**	8	**A**	13	**D**	18	**C**	23	**A**	28	**B**	33	**B**	38	**D**
4	**B**	9	**D**	14	**B**	19	**B**	24	**D**	29	**C**	34	**A**	39	**A**
5	**B**	10	**D**	15	**A**	20	**B**	25	**C**	30	**D**	35	**A**	40	**B**

Suggested Solutions

1 A

$$\text{unit of } \eta = \frac{\text{kg m s}^{-2}\ \text{m}^2}{\text{m}^3\ \text{m s}^{-1}} = \text{kg m}^{-1}\ \text{s}^{-1}$$

2 C

$$s_1 + s_2 = u(t_1 + t_2) - \frac{1}{2}g(t_1 + t_2)^2 \quad \text{.... (1)}$$

$$v = u - g(t_1 + t_2) \quad \Rightarrow u = g(t_1 + t_2) \quad \text{.... (2)}$$

Sub. (2) into (1),

$$s_1 + s_2 = g(t_1 + t_2)^2 - \frac{1}{2}g(t_1 + t_2)^2$$

$$\therefore s_1 + s_2 = \frac{1}{2}g(t_1 + t_2)^2$$

3 D Since the ball bearing is released from rest, its initial speed is zero. Hence at t = 0 s, it is a stationary point on the graph.

The ball bearing accelerates downwards under the pull of gravity until it enters the oil. During this part of the motion, the gradient of the graph increases.

In the oil, the ball bearing will experience a resistive force upwards that is greater than its weight. This will cause the ball bearing to decelerate. During this part of the motion, the gradient of the graph decreases.

When the resistive force decreases (speed is decreasing) until it is equal in magnitude to its weight, the ball bearing will travel downwards with constant speed until it hits the bottom of the cylinder and comes to a sudden stop. During this part of the motion, the gradient of the graph is constant and will become zero abruptly.

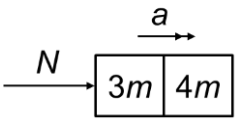
4 B When the rock is dropped into the lake, it sinks as the upthrust on it is smaller than its weight. This means the weight of the water displaced is smaller than the weight of the water displaced when the rock is on the boat.

5 B

$$F\cos 50° = mg\sin 20°$$

$$F = 26.1\ \text{N}$$

6 **C** $F = 10ma$



$$N = 7ma = 7m\left(\frac{F}{10m}\right) = 0.7F$$

7 **B** Newton's 2nd Law.

8 **A** By the principle of conservation of energy

$$GPE_{M(initial)} + GPE_{N(initial)} = GPE_{N(final)} + KE_{M\&N(final)}$$

$$(5.0)g(0.30) + (3.0)g(0.30) = (3.0)g(0.60) + \frac{1}{2}(5.0+3.0)v^2$$

$$v = 1.21 \text{ m s}^{-1}$$

Or use kinematics to solve

9 **D**

$$\text{mass flow rate} = \frac{\Delta m}{\Delta t} = \frac{V\rho}{t} = \frac{Ah\rho}{t} = A\rho v = (1000)\left(5.0\times10^{-4}\right)(1.5) = 0.75 \text{ kg s}^{-1}$$

$$\text{rate of change of GPE} = \frac{mgh}{t} = \frac{\Delta m}{\Delta t}(gh) = (0.75)(9.81)(3.0) = 22.0725 \text{ W}$$

$$\text{rate of change of KE} = \frac{1}{2}\frac{mv^2}{t} = \frac{1}{2}\frac{\Delta m}{\Delta t}\left(v^2\right) = \frac{1}{2}(0.75)(1.5)^2 = 0.844 \text{ W}$$

$$\text{output Power} = 22.0725 + 0.844 = 22.91625 \text{ W}$$

$$\text{input power} = 45.8 \text{ W}$$

10 **D** At Y, the string is just taut.

$T = 0 \quad \therefore F_C = mg$

$$\frac{mv^2}{r} = mg \quad \Rightarrow v_{top}^2 = gr = gl$$

Conservation of Energy

$$\frac{1}{2}mv_{bottom}^2 = \frac{1}{2}mv_{top}^2 + mgh$$

$$v_{bottom} = \sqrt{2\left(\frac{1}{2}(gl) + g(2l)\right)} = \sqrt{5gl}$$

11 **C**

$$f = \frac{mv^2}{r} \quad \Rightarrow \frac{f}{mg} = \frac{v^2}{rg} = \frac{(40)^2}{80(9.81)} = 2.0$$

12 B

$$\frac{g_{planet}}{g_{earth}} = \frac{\rho_{planet} R_{planet}}{\rho_{earth} \mathrm{R}_{earth}} = 6$$
$$g_{planet} = 6g_{earth}$$

$$\frac{1}{2} g_{earth} t_{earth}{}^2 = \frac{1}{2} g_{planet} t_{planet}{}^2$$
$$\frac{1}{2} g_{earth} t_{earth}{}^2 = \frac{1}{2} (6g_{earth}) t_{planet}{}^2$$
$$\frac{1}{\sqrt{6}} t_{earth} = t_{planet}$$

$$100 = \frac{1}{2}(9.81) t_{earth}{}^2$$
$$t_{earth} = 4.5 \text{ s}$$
$$t_{planet} = 1.8 \text{ s}$$

Difference in time of flight = 4.5 – 1.8 = 2.7 s

13 D Area under $g - r$ graph gives the magnitude of the change in gravitational potential

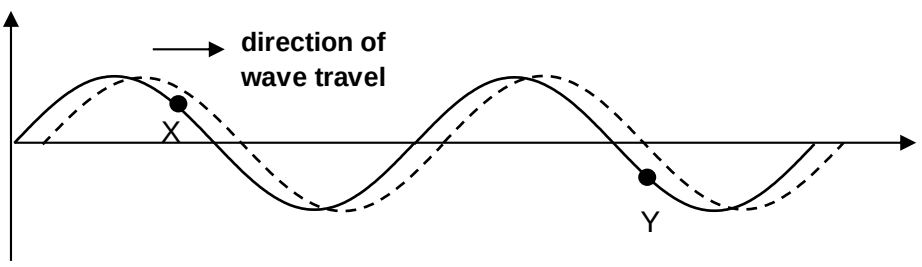
Min speed when $v = 0$ at $g = 0$
Loss in GPE from max point to Earth = Gain in KE
$$m\Delta\phi = \frac{1}{2} mv^2$$
$$61 \times 10^6 = \frac{1}{2} v^2$$
$$v = 11000 \text{ m s}^{-1}$$

14 B

$$F_0 = m\omega^2 x_0$$
$$10 = (2)\left(\frac{2\pi}{T}\right)^2 (0.05) \quad \Rightarrow T = 0.63 \text{ s}$$

15 A Elastic potential energy is proportional to the square of the extension of the spring.
Gravitational potential energy (near the surface of the Earth) is proportional to vertical distance.
Kinetic energy is zero at the extreme ends of the oscillation and maximum at the equilibrium.

16 C



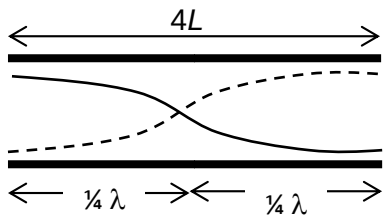
17 A $0.7I_0 = I_0 \cos^2\theta$

In the first quadrant, $\theta = 33°$

In the third quadrant, $\theta = 180° + 33° = 213°$

18 C $\lambda = 8L$

$\frac{1}{4}\lambda = 2L$



19 B Grating X produces horizontal spread of interference fringes.

Distance between first order fringe and central maxima = 0.5 m

$\tan\theta = \frac{0.5}{3.6}$

$\theta = 7.90716°$

$d\sin\theta = 1\lambda$

$d = \frac{\left(450\times10^{-9}\right)}{\sin\left(7.90716°\right)} = 3.2711\times10^{-6}$ m

Number of lines per m $= \frac{1}{d} \approx 3\times10^{5}$ m^{-1}

20 B

Using $P = \frac{dm}{dt}c\Delta\theta + \frac{dm}{dt}\times l_V$,

$$\frac{dm}{dt} = \frac{P}{c\Delta\theta + l_V} = \frac{2000}{4200\times\left(100-20\right)+2.2\times10^{6}} = 7.9\times10^{-4}\ \text{kg s}^{-1}$$

21 C

average KE, $E = \frac{3}{2}kT$

E is proportional to T. If E is increased by 4 times, T will also be increased by 4 times.

Since volume of rigid container is constant,

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$p_2 = \frac{p_1}{T_1}T_2 = \frac{p_1}{T_1}\left(4T_1\right) = 4p_1$

Hence pressure will also increase by 4 times.

22 B The total amount of gas is constant:

$$2\times\frac{PV}{RT}=\frac{P_1V}{RT}+\frac{P_1V}{R\times 2T}=\frac{3P_1V}{2RT}$$

Rearranging,

$$P_1=\frac{4}{3}P$$

23 A Electric current is the rate of flow of charges. Since the number of charges per unit time at P, Q and R are the same, the current is the same at all three places.

24 D

$$dR=\frac{\rho dr}{2\pi rh}$$

$$\int dR=\frac{\rho}{2\pi h}\int_d^r\frac{1}{r}dr$$

$$R=\frac{\rho}{2\pi h}\left(\ln r-\ln d\right)$$

25 C The equivalent resistance is 333 Ω (R_2 in parallel with 500 Ω) so p.d. across R_2 is lower while that across R_1 is higher. Hence lower current through R_2.

Total resistance is lower so current supplied by battery is greater.

p.d. across R_1 is greater than that across R_2 using potential divider rule.

26 B Potential divider rule:

$$V=\frac{3.00}{3.00+2.00+R}\times 2.00=6.00\times 10^{-3}$$

Rearranging,

$$R=995\ \Omega$$

27 A

$$|F|=\frac{dU}{dx}$$

$$|a|=\frac{dU}{mdx}=\frac{3.2\times 10^{-18}}{1.67\times 10^{-27}\times 0.050\times 10^{-2}}$$

$$\therefore |a|=3.8\times 10^{12}\ \text{m s}^{-2}$$

28 B The resultant electric field strength at the centre of the square for B will be pointing to the right horizontally and greatest in magnitude.

29 C

$$F=NBIL$$

$$\tau=Fd$$

$$=(NBIL)d$$

$$=(20)(0.80)(5.0)(0.20)\times(0.20)\cos 30°$$

$$=2.8\ \text{N m}$$

30 D If Y is rotated in the opposite direction, the magnitude of the resultant magnetic flux density at P will similarly decrease to $\sqrt{2}$ times the flux density due to each wire at P. Only the direction of the resultant flux density will be different.

31 C OP sweeps a smaller area than OQ. Hence a smaller e.m.f. is induced across OP.
Potential at P is higher than the potential at Q. When a resistor is connected across PQ, a current will flow out of P, through the resistor, and into Q.
The current in the rod will be from Q to P.

32 A
$$I = I_0 \sin \omega t = \sqrt{\frac{P_0}{R}} \sin \frac{2\pi}{T} t = \sqrt{\frac{150}{6.0}} \sin \frac{2\pi}{0.020} t$$
$$I = 5.0 \sin 100\pi t$$

33 B Thicker wires will result in lower resistance in the wires and power loss will be less.

34 A Since the metal did not change, the characteristic x-rays stay at the same frequencies
When the potential difference is increased, KE of incident electron is increased, resulting in more 'braking radiation'. Hence the intensity of x-ray produced across all frequency tend to increase. This causes the peak intensity to increase as well.
Maximum frequency depends on accelerating voltage. Since accelerating voltage increase, then maximum frequency increases.

35 A $p = mv = (9.11 \times 10^{-31})(1.50 \times 10^{6}) = 1.37 \times 10^{-24}$ kg m s^{-1}
$\Delta p = 0.002\ p = 0.002(1.37 \times 10^{-24}) = 2.74 \times 10^{-27}$ kg m s^{-1}
$\Delta x = h/(2 \times 2\pi \Delta p) = 1.05 \times 10^{-34} / (2 \times 2.74 \times 10^{-27}) = 1.92 \times 10^{-8}$ m

36 B An insulator has the largest band gap with the conduction band totally empty.
A p-type semiconductor has a small band gap with acceptor energy levels just above the valence band.
A metal has a completely filled valence band and a partially filled conduction band.

37 A Under the forward bias condition, the majority charge carriers will move across the junction. So holes from the p side will move to the n side and electrons in the n side will move to the p side.

38 D The Rutherford's scattering experiment studies the deflections of the alpha particles. Only the nucleus is massive enough to cause significant deflections.

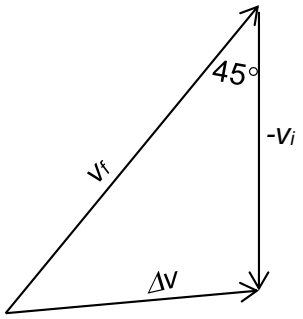
39 A
$$A_{P0} + A_{Q0} = 800 \qquad (1)$$
$$A_{P0}\left(\frac{1}{2}\right)^{120/60} + A_{Q0}\left(\frac{1}{2}\right)^{120/30} = 80$$
$$\frac{1}{4}A_{P0} + \frac{1}{16}A_{Q0} = 80$$
$$\Rightarrow 4A_{P0} + A_{Q0} = 1280 \qquad (2)$$
(2) – (1) :
$$3A_{P0} = 480$$
$$A_{P0} = 160$$

40 B Only α decay results in a change in mass number, and each α decay causes the mass number to decrease by 4. Hence the difference in the mass number of the end product and the parent nuclide must be a multiple of 4.

2016 Raffles Institution Preliminary Examination

H2 Physics Paper 2 – Solutions

1 (a)



$\Delta v^2 = 220^2 + 240^2 - 2(220)(240)\cos 45^\circ$ M1

$\Delta v = 177 \text{ m s}^{-1}$ A1

(b) (i) distance travelled by van = distance travelled by police car

$20t = \frac{1}{2}(2.5)t^2$ M1

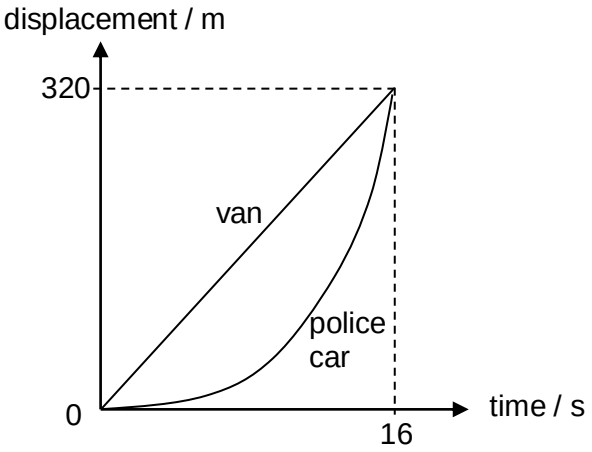
$\frac{1}{2}(2.5)t^2 - 20t = 0$

$t(1.25t - 20) = 0$

$t = 0$ s or $t = 16$ s

distance travelled = 20 t = 20 × 16 = 320 m A1

(ii)



B1
B1

*Straight line for van
*Parabolic for police car
*Correct labels
*3 correct – 2 mks
*2 correct – 1 mk

(iii) 1. $v = u + at$

$= 0 + 2.5(16 + 0.30)$

$= 40.75$

$= 41 \text{ m s}^{-1}$

M1

2. Speed of police car at the point of overtaking van

$v = 2.5 \times 16 = 40 \text{ m s}^{-1}$

Distance travelled in 0.30 s after policeman sees tree and applies brakes

$s_1 = 40 \times 0.30 + \frac{1}{2} \times 2.5 \times 0.30^2 = 12.1\,1 \text{ m}$ M1

Distance travelled from the point brakes are applied till car comes to rest

$0 = 41^2 - 2 \times 8.0 \times s_2$ M1

$s_2 = 105.1 \text{ m}$

Total distance $s = s_1 + s_2 = 12.11 + 105.1 = 117.2$ m

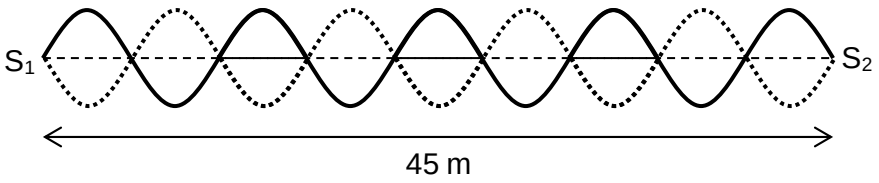
Since this distance is less than 130 m, the police car manages to stop in time. A1

2 **(a)** **(i)** The radiowaves from S_1 and S_2 meet along the line S_1S_2 with varying path difference. When the path difference is an integer multiple of a wavelength (i.e. $n\lambda$), constructive interference occurs and a maxima is detected. B1
When the path difference is an odd integer multiple of half a wavelength (i.e. $(n+1/2)\lambda$), destructive interference occurs and a minima is detected. B1

OR

The maxima and minima give rise to fluctuations in intensity along S_1S_2.
Since the radio waves from S_1 and S_2 have the same frequency, amplitude, speed and are travelling towards one another, a stationary wave is set up along the line S_1S_2.
The nodes and antinodes of the stationary wave would correspond to the minimum and maximum intensity detected respectively.

(ii)



45 m = 4.5 wavelengths M1
Wavelength = 10 m A1

(b) **(i)** S_1S_2A is an equilateral triangle
Path difference at point A = $S_1A - S_2A = 0$

Hence, intensity is a maximum. A1

(ii) Path difference at point B = $S_1B - S_2B = 90 - 45 = 45 \text{ m} = 4.5\,\lambda$

Hence, intensity is a minimum. A1

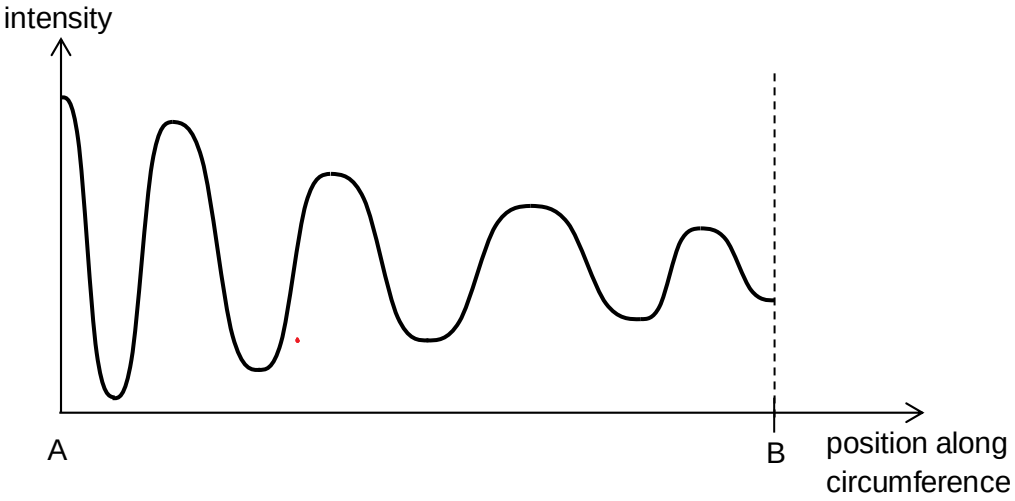
(iii) At point B
Amplitude of wave from $S_1 = ½\,a$
Amplitude of wave from $S_2 = a$

Amplitude of resultant wave = $a - ½\,a = ½\,a$ (destructive interference at B) M1

Since intensity $\propto$ (amplitude)^2

$I \propto \left(\frac{1}{2}a\right)^2 = \frac{1}{4}a^2$ M1

(iv)



B1
B1

*B1 – Maxima at A, minima at B, 4 maxima in between A and B
*B1 – Intensity of each maxima decreases and of each minima increases
*Horizontal spacing between maxima and minima not marked

(v) **1.** The graph would show fewer maxima and minima. B1

2. The positions of maxima and minima are interchanged. B1

3 **(a)** Total resistance when A and B is short-circuited is $r + 297$.
This causes a current of 5.00 mA to flow through the milliammeter.
Hence

$$1.50 = 5.00 \times 10^{-3} \times (r + 297)$$

M1

Solving,

$r = 3\ \Omega$ (Nearest ohm) A1

(b) Deflection at half the full-scale implies $I = 2.50$ mA.
Hence,

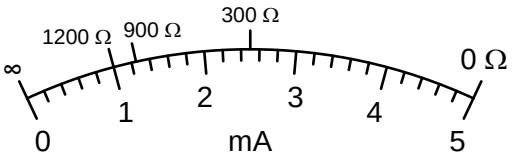
$$1.50 = 2.50 \times 10^{-3} \times (R + 300)$$

M1

Solving,

$R = 300\ \Omega$ A1

(c)



*Marks are awarded for correct marking positions (within ¼ division) and correct labels.
*2 correct markings with correct labels – 1 mk B1
*4 correct markings with minimum of 3 correct labels – 2 mks B1

(d) The smallest current detectable by the milliammeter is 0.1 mA, corresponding to a resistance of ~15 kΩ (14.7 kΩ to be exact).
OR
The current flowing in the circuit when 50 kΩ is connected between AB is 0.03 mA. M1
This is smaller than the smallest division of the milliammeter scale.

So 50 kΩ cannot be measured with reasonable precision. A1

4 **(a)** $E = \Phi + E_{K,\max}$ Minus 1m for each error.

where
E is the energy of a photon of the incident light,
Φ is the work function of a metal and
$E_{K,\max}$ is the maximum kinetic energy of the photoelectrons.

(b) **(i)** The rate at which electrons are reaching Y is equal to the rate at which electrons are reaching X. B1

(ii) As the potential of Y is lowered as compared to X, there will reach a point when no photoelectrons from X reach Y and all the photoelectrons from Y reach X. Current is hence saturated. B1

(iii) **1.** Using information for Y:

$$E = \Phi + eV_s$$
$$= \left(1.60 \times 10^{-19}\right)\left(3.4 + 0.74\right)$$
$$= 6.62 \times 10^{-19} \text{ J}$$ A1

Note: can also use data for X to calculate

2. rate of incidence of photons on Y,

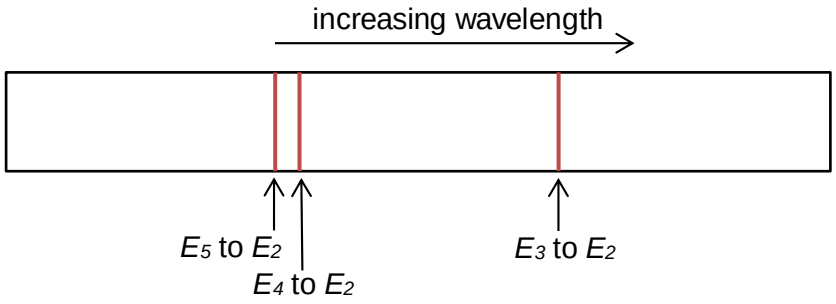
$$\frac{n_p}{t} = \frac{n_e / t}{t} = \frac{I / e}{t} = \frac{4.0 \times 10^{-9}}{\left(1.0 \times 10^{-6}\right)\left(1.60 \times 10^{-19}\right)} = 2.5 \times 10^{16}$$ M1

intensity on Y,

$$i = \frac{n_p}{t}\frac{E}{A}$$
$$= \left(2.5 \times 10^{16}\right)\frac{\left(6.62 \times 10^{-19}\right)}{7.9 \times 10^{-3}}$$ M1
$$= 2.09$$
$$= 2.1 \text{ W m}^{-2}$$

(c) **(i)** 10 B1

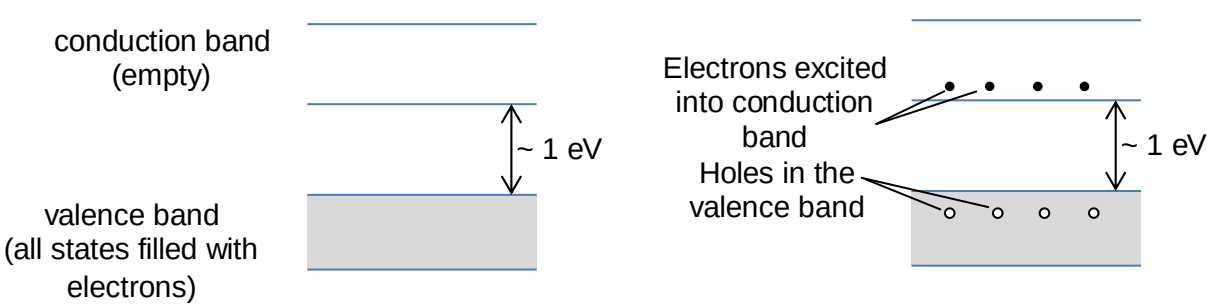
(ii) Transitions that are within the visible light region are observable:
E_5 to E_2, E_4 to E_2, E_3 to E_2.



B1
B1

*Only 3 lines
*Correct labels (E_5 to E_2 etc)
*Relative spacing between the 3 lines.

5 **(a)**



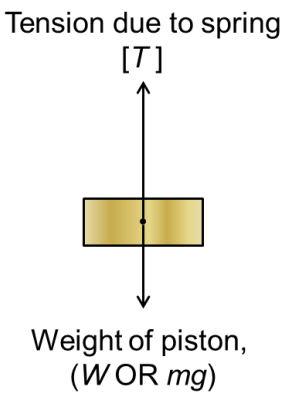
When temperature increases, more electrons acquire enough energy to overcome the small band gap and cross over to the conduction band leaving holes in the valence band. B1

The electrons in the conduction band and the holes in the valence band both act as mobile charge carriers. B1

The increase in the number of electrons in the conduction band and holes in the valence band increase the electrical conductivity and decrease its electrical resistance. The higher the temperature, the more electrons will move to the conduction band and resistance continues to decrease. B1

(b) By adding Group 5 atoms to the intrinsic semiconductor, the additional electron of each atom will occupy some discrete energy levels just below the conduction band. B1
These additional electrons that are just below the conduction band are easily excited into the conduction band and contribute to the increase in the electrical conductivity of the semiconductor. B1

6 (a) (i)



B1

*Accept any reasonable symbols used

(ii) Taking downwards as positive:
using Newton's second law,

$mg - k(x_0 + x) = ma$ where x_0 is the extension of the spring at equilibrium M1

$mg - kx_0 - kx = ma$

$mg - mg - kx = ma$ since $mg = kx_0$ when piston is at equilibrium

$ma = -kx$

$a = -\frac{k}{m}x$ A1

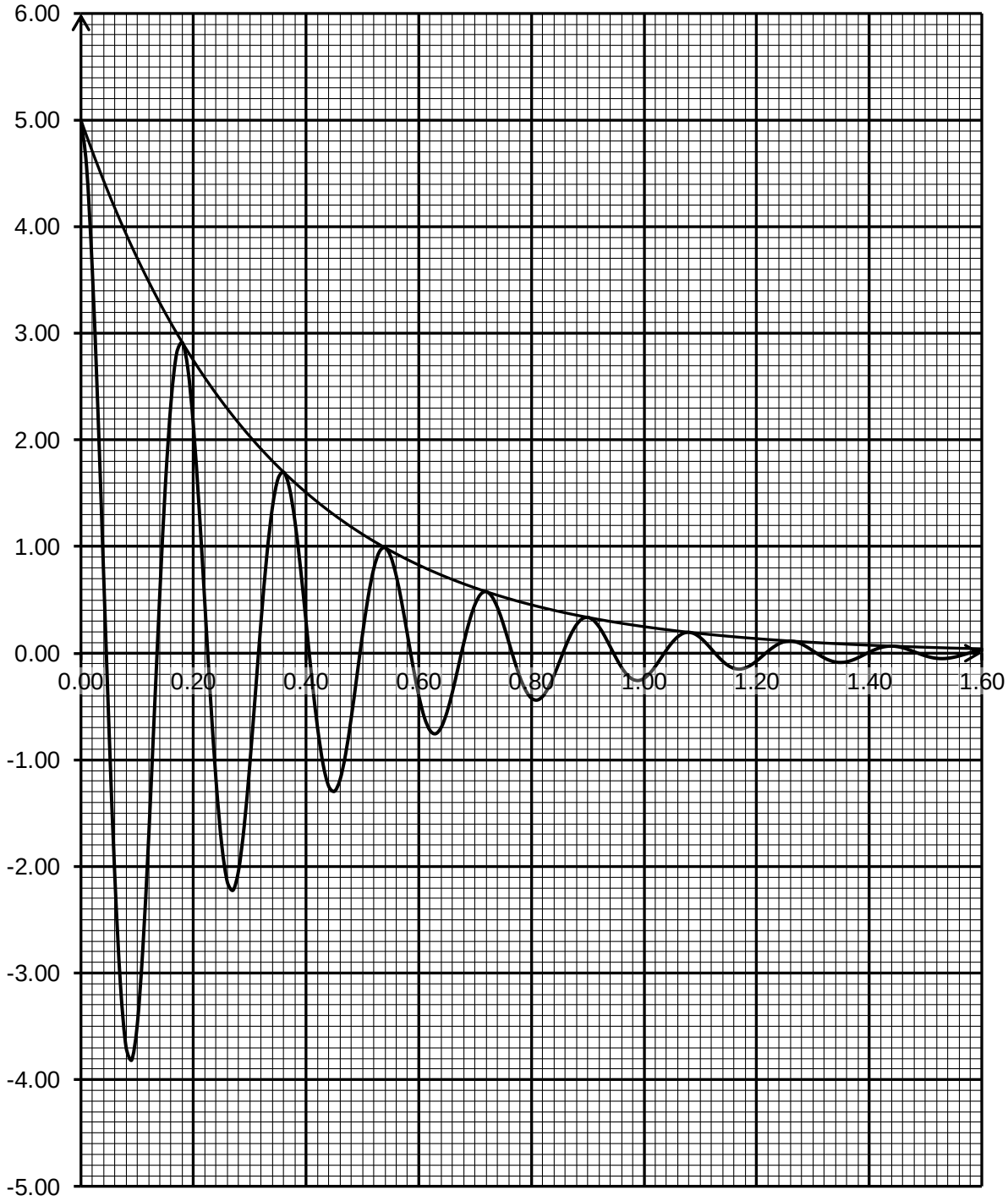
*clear working with appropriate explanation is expected

(iii) Since $\frac{k}{m}$ is a constant, $a \propto -x$.

This implies 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. This is consistent with the definition for simple harmonic motion where $a = -\omega^2 x$.

B1

B1



(b) (i) 1. 1.10 cm to 1.15 cm A1

2. The addition of oil provides resistance to the motion of the piston.
Damping occurs and there is energy loss from the oscillating system as work is done against resistive forces. B1
This causes the amplitude of the oscillation to decrease with time.

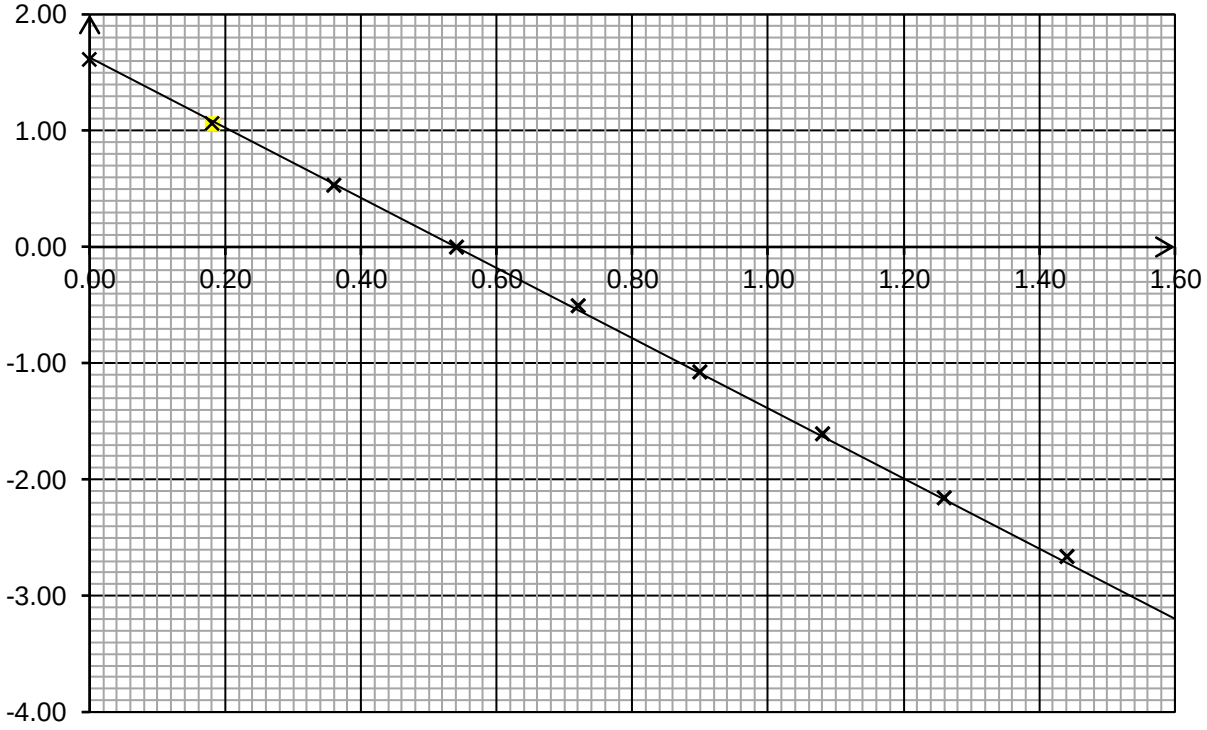
(ii)

t /s	*A* /cm	ln (*A* /cm)
0.18	**2.90**	**1.065**
	2.91	**1.068**
	2.92	**1.072**
	2.93	**1.075**
	2.94	**1.078**

A1

(iii) **1.** See the graph below. B1

2. See the graph below. (allow e.c.f.) B1



3. $A = A_0 e^{-\gamma t}$

$\ln A = \ln A_0 - \gamma t$

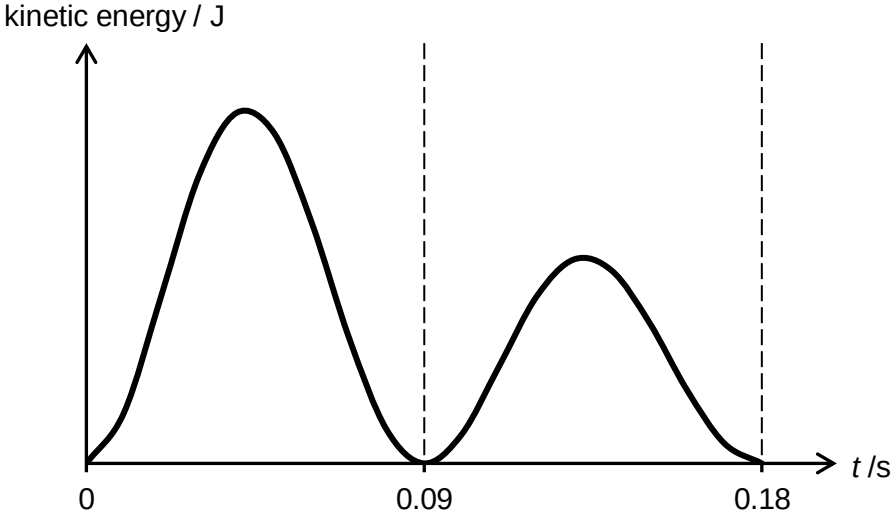
A graph of ln A against t will give a straight line graph with gradient $-\gamma$ and vertical intercept ln A_0. M1

Gradient coordinates read to half the smallest division precision. M1

Calculation

$\gamma = 2.91$ to $3.03\ s^{-1}$ A1

(iv)

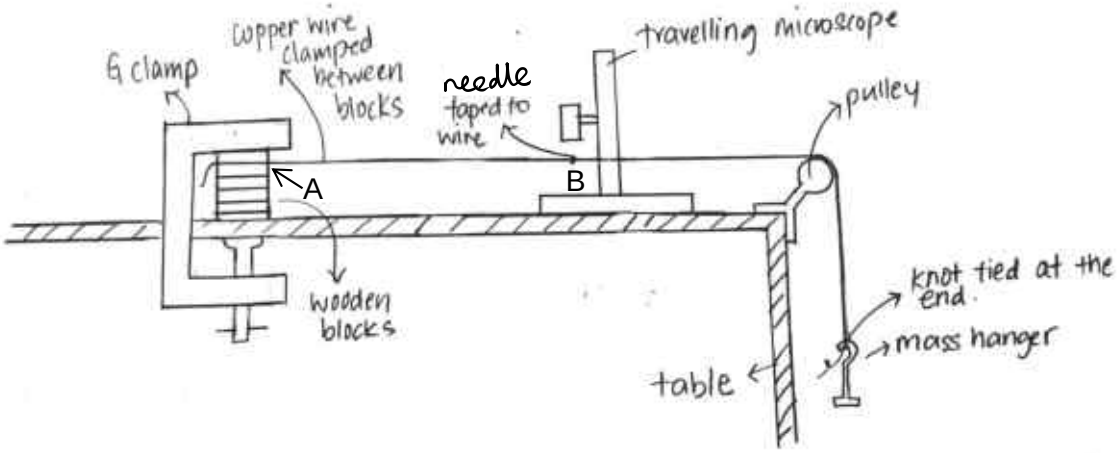


B1

*minimum and maximum values of KE at the correct positions
*decrease in the maximum KE value

(c) The damping coefficient is likely to be <u>higher</u> so that the vehicle suspension <u>system approaches critical damping</u>, thus preventing the vehicle from bouncing (oscillating) continuously after going over a hump or pothole. B1

7 Diagram



Identification of variables

Independent variable: force F on copper wire
Dependent variable: extension ΔL of copper wire
Control variables: cross-sectional area A of the copper wire, original length L_0 of the copper wire

Procedure

1. Set up the apparatus as shown in the diagram above.
   Tape a needle to the copper wire, nearer to the pulley.

2. Use a metre rule to measure the original length L_0 of the wire from point A on the copper wire to the needle at point B and record.

   Use a micrometer screw gauge to measure the diameter d of the wire and record.

   Calculate the original cross-sectional area of the copper wire using $A = \frac{\pi d^2}{4}$.

3. <u>To determine extension ΔL</u>
   Record the reading x_1, on the vernier scale of the travelling microscope at which the needle is at.

   Add some slotted masses to the mass hanger until there is an observable extension of the copper wire on the travelling microscope. Record the mass added as Δm.

   Record the new reading x_2, on the travelling microscope at which the needle is at.
   Calculate the extension of the wire using $\Delta L_1 = (x_2 - x_1)$.

   (To obtain readings x_1 and x_2, look through the travelling microscope and adjust till the intersection point of the cross hair is at the needle.)

4. <u>To determine force F</u>
   Calculate the force acting on the wire that results in ΔL_1 using $F = mg$
   where $m = n(\Delta m)$ and n is the integer multiple of Δm.

5. <u>To check for range of mass (and hence force)</u>
   Add slotted masses equivalent to 8 times of Δm to the mass hanger and wait for a while. Then remove all the slotted masses and check if the wire returns to its original length. If so, then the experiment can be continued. If not, use a new longer copper wire, reduce the value of Δm and repeat steps 3 to 5.

6. Repeat steps 3 and 4 to obtain 7 further sets of readings of F and ΔL_1 by adding slotted masses in intervals of Δm to the mass hanger each time until 8 times of Δm.

7. Repeat the experiment by removing the slotted masses in intervals of Δm each time and calculate the extension ΔL_2 for each set of readings of m and F.

8. Calculate the average extension $\langle \Delta L \rangle$ for each set of readings of m and F using $\langle \Delta L \rangle = (\Delta L_1 + \Delta L_2)/2$.

Control variables

Keep the cross-sectional area A of the copper wire constant by using the same wire throughout the experiment.

Measure the original length L_0 of the copper wire with a metre rule before each set of reading is taken to check that it remains constant throughout the experiment i.e. positions of points A and B do not change.

Analysis

$$E = \frac{F}{A}\frac{L_0}{\Delta L}$$

$$F = \frac{EA}{L_0}\Delta L = c\Delta L \quad \text{where c} = \frac{EA}{L_0}$$

Plot a graph of force F against ΔL. Draw a best-fit line.
Calculate the gradient, c of the best-fit line.
Calculate $E = c\frac{L_0}{A}$.

Safety precaution

1. Wire may snap or come loose if the force applied is too large or if the wire is not secured tightly, and the masses may fall on the floor and break. Place a mat on the floor directly below the hanging masses to cushion the fall of the masses.

Methods to increase the reliability of the results

1. Use a longer wire or a thinner wire to get a greater extension of the wire for each of the applied mass/force.

2. Check that the wire has no kinks so that the measured length and extension will be accurate.

3. Use the vernier scale on a travelling microscope to measure the extremely small extension to a greater precision.

4. As the wire can be non-uniform, measure the diameter of the copper wire at different points along the wire and in different directions and obtain an average value of the diameter. This will give a more accurate value for the cross-sectional area of the wire.

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Mark Scheme

Diagram or description (1 mk)

- Wire held in place at one end (with wooden blocks), loaded at the other end in the directioni of the length of the wire

Procedure (6 mk)

- Method to vary force *F* by varying mass and calculate *F* = *mg*.
- Method to determine extension $\Delta L = x_2 - x_1$.
- Method to determine possible range of mass/force such that wire does not deform permanently i.e. check that wire returns to original length.
- Method to determine the increase in mass that will extend the wire sufficiently.
- Method to determine the original length L_0 (include the use of a pointer).
- Method to determine the cross-sectional area *A* of the copper wire (include the use of a micrometer screw gauge to measure diameter and the equation relating area and diameter).

Control variables (1 mk)

- Method to ensure cross-sectional area and original length of the copper wire remains constant.

Analysis (1 mk)

- Minimum 6 sets of readings to plot a straight line graph.
- Plot a graph of force *F* against ΔL and determine the gradient *c* of the straight line graph.
- Calculate $E = c\frac{L_0}{A}$

Safety precautions (1 mk) – must give risk & how to prevent hazard

- Wire may snap or come loose if the force applied is too large and the masses may fall on the floor and break. Place a mat on the floor directly below the hanging masses to cushion the fall of the masses.

Methods to increase reliability of results (max. 3 mk) – must explain why

- Use a longer wire or a thinner wire to get a greater extension of the wire for each of the applied mass/force.
- Wire has no kinks so that the measured length and extension will be accurate.
- Repeat experiment to obtain second set of readings for ΔL and determine average.
- Use of travelling microscope to measure the small extension precisely.
- Measure the diameter of the wire at different points along the wire and in different directions and obtain average.

2016 Raffles Institution Preliminary Examination

H2 Physics Paper 3 – Solutions

Section A

1 (a) By conservation of energy,

Loss in EPE of the spring = Gain in KE of block A

$$\frac{1}{2}kx^2 - 0 = \frac{1}{2}(m_A)u^2 - 0$$ M1

$$k(0.020)^2 = (1.5)(0.50)^2$$

$$k = 937.5 = 938 \text{ N m}^{-1}$$ A1

(b) By the conservation of momentum:

$$m_A u = m_A v_1 + m_B v_2$$

$$1.5(0.50) = (1.5)v_1 + (0.50)v_2$$ M1

$$0.75 = 1.5v_1 + 0.50v_2$$

Relative speed of approach = relative speed of separation

$$u = v_2 - v_1$$

$$0.5 = v_2 - v_1$$ M1

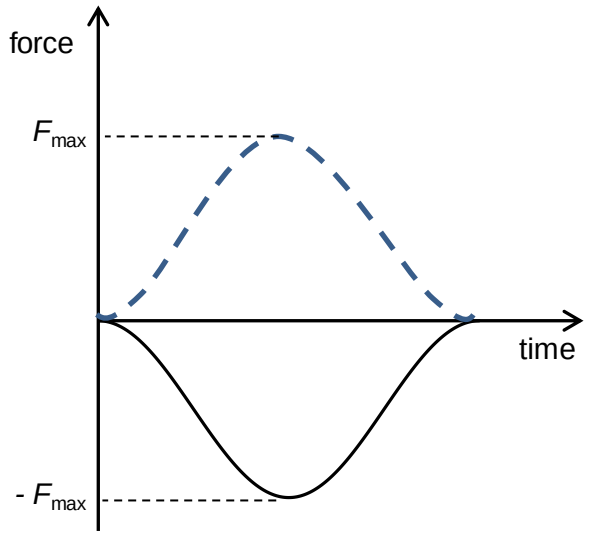
$$v_1 = v_2 - 0.5$$

Sub into above

$$0.75 = 1.5(v_2 - 0.5) + 0.50v_2$$

$$v_2 = 0.75 \text{ m s}^{-1}$$ A1

(c) (i)



B1

(ii) Area under the force time graph is the change in momentum of a body. The area under the graphs of A and B are equal in magnitude but opposite in direction. B1

This implies that the gain in momentum of one block is equal to the loss in momentum of the other. B1

(d) Even though total kinetic energy is conserved, the kinetic energy of A is now less than before as some of its kinetic energy has been transferred to B. M1

By conservation of energy, energy transferred to the spring will therefore be less and the compression of the spring will be less than 2.0cm. A1

2 **(a)** 1. Its direction of rotation is the same as that of the Earth about its axis of rotation (eastward). B1

2. Its orbit lies in the same plane as the Equator (or always above the Equator). / Its orbit must be concentric with the Equator. B1

(b) **(i)**

$$F_G = F_C$$

$$\frac{GMm}{R^2} = mR\omega^2$$

$$R = \sqrt[3]{\frac{GM}{\omega^2}}$$ M1

$$v = R\omega$$

$$= \sqrt[3]{\frac{GM}{\omega^2}}\omega$$

$$= \sqrt[3]{GM\omega}$$

$$= \sqrt[3]{\left(6.67\times10^{-11}\right)\left(5.99\times10^{24}\right)\left(\frac{2\pi}{24\times60\times60}\right)}$$ M1

$$= 3070 \text{ m s}^{-1}$$

(ii) Minimum energy required to place satellite in orbit

= Gain in GPE + Gain in KE

$$= m\Delta\phi + \frac{1}{2}mv^2$$ M1

$$= (670)\left[\left(7.19\times10^6\right) + \frac{1}{2}(3070)^2\right]$$ A1

$$= 7.97\times10^9 \text{ J}$$

(c) **(i)**

$$F_G = F_C$$

$$\frac{GMm}{R^2} = \frac{mv^2}{R}$$

$$v = \sqrt{\frac{GM}{R}}$$

$$K = \frac{1}{2}m\left(\sqrt{\frac{GM}{R}}\right) = \frac{GMm}{2R}$$

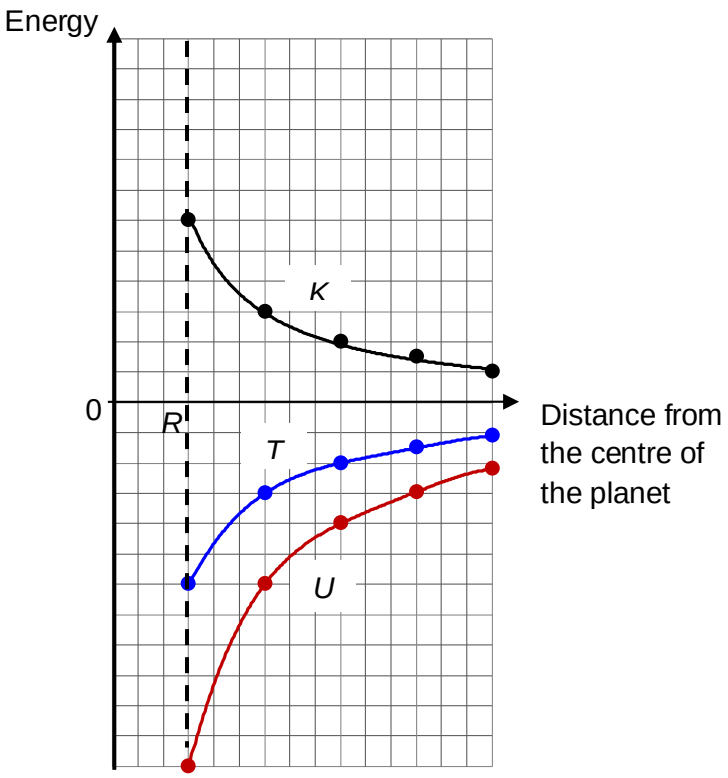
$$U = -\frac{GMm}{R}$$ M1

Hence,

$$K = -\frac{1}{2}U$$

$$2K + U = 0$$ M1

(ii)

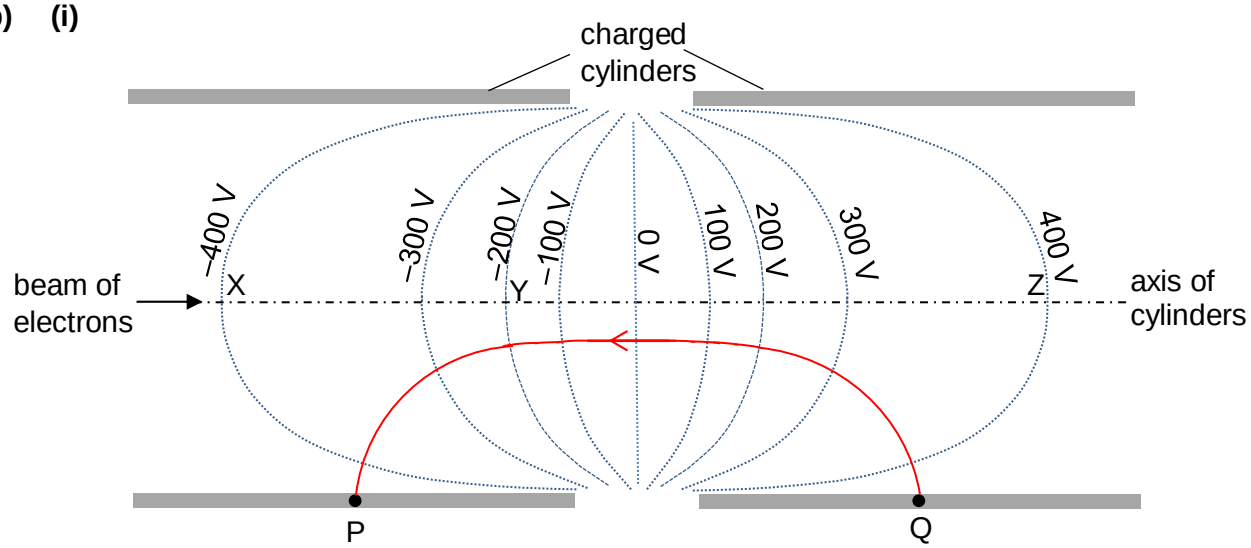


B1
B1

*B1 – for *U* graph
*B1 – for *T* graph
*Points must be correctly plotted.

3 **(a)** The electric field strength at a point in an electric field is defined as the <u>force per unit charge acting on a small positive test charge</u> placed at that point. B1

(b) **(i)**



*B1 – Electric field line drawn should be smooth and normal to each of the equipotential line
*B1 – Direction of electric field line pointing from higher to lower potential indicated

(ii) **1.** Using law of conservation of energy

Gain in KE = Loss in EPE

$$\frac{1}{2}m(v^2-u^2)=q\Delta V$$

$$\therefore v=\sqrt{\frac{2q(V_Z-V_X)}{m}+u^2}$$

$$v=\sqrt{\frac{2\times1.60\times10^{-19}\times\left[400-(-400)\right]}{9.11\times10^{-31}}+(8.0\times10^5)^2}$$ M1

$$v=1.68\times10^7 \text{ m s}^{-1}$$ A1

2.

$$E=\left|\frac{\Delta V}{\Delta x}\right|$$

$$E=\frac{300-100}{1.80\times10^{-2}}$$ M1

$$\therefore E=1.11\times10^4 \text{ V m}^{-1}$$ A1

*check actual measurement on students' question paper

3. $F=Eq$

$$F=1.11\times10^4\times1.60\times10^{-19}$$

$$\therefore F=1.78\times10^{-15}\text{N}$$ A1

(c) The kinetic energy of the ion will remain the same. A1

The potential at the entrance is the same as the potential at the exit. There will be no change in the potential energy of the ion and hence no change in the kinetic energy of the ion. M1

4 **(a)** **(i)** The velocity of each charged particle is perpendicular to the magnetic flux density. Each charged particle experiences a magnetic force that is always perpendicular to its velocity and the magnetic flux density. B1

This changes the direction of the velocity but not its magnitude.
Hence, magnetic force is constant in magnitude and the path of each charged particle is circular. B1
OR
Hence no work is done on the charged particle, and its speed remains constant. Hence, magnetic force is constant in magnitude and the path of each charged particle is circular.

(ii) Negative B1

(iii)

$$F_B = \frac{mv^2}{r}$$

$$Bqv = \frac{mv^2}{r}$$ M1

$$q = \frac{mv}{Br}$$

$$q_1 = \frac{mv}{Br_1} \quad , \quad q_2 = \frac{mv}{Br_2}$$

$$\frac{q_2}{q_1} = \frac{r_1}{r_2} = \frac{r_1}{2r_1} = 0.50$$ A1

(b) (i) As particle X ionises (collides with) the gas particles, it loses energy. Particle X loses kinetic energy and its speed decreases. B1

$$Bqv = \frac{mv^2}{r}$$

$$r = \frac{mv}{Bq_1}$$

From the equation, the radius of circular path is proportional to speed. B1
Hence as the speed of X decreases, the radius of its circular path will also decrease. X spirals inwards with decreasing radius.

(ii) 1.

$$Bq_X v = \frac{mv^2}{r}$$ M1

$$\frac{v}{r} = \frac{Bq_X}{m}$$

$$\omega = \frac{Bq_X}{m}$$

$$\frac{2\pi}{T} = \frac{Bq_X}{m}$$

$$T = \frac{2\pi m}{Bq_X}$$ A1

Note: Angular velocity and period is independent of speed and radius.

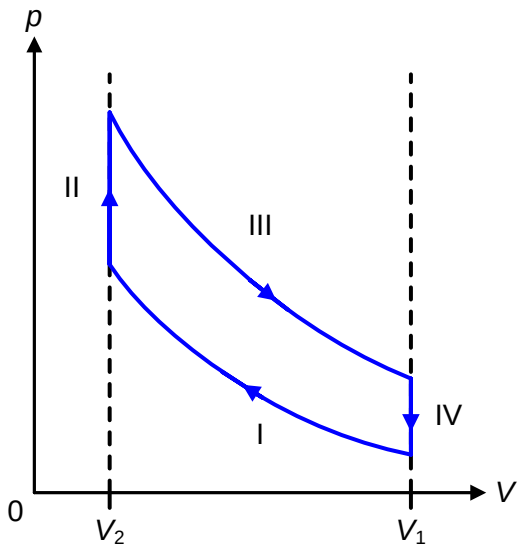
2.

$$T = \frac{2\pi m}{Bq_X} = \frac{2\pi(3000)\left(9.11\times10^{-31}\right)}{(1.0)\left(1.60\times10^{-19}\right)} = 1.07\times10^{-7} \text{ s} \quad \textit{(Must find!)}$$

Particle X cannot be a tau particle as the lifetime of the tau particle is shorter than one period. The tau particle will decay before it can spiral. B1

Section B

5 (a)



B1
B1

*Marking point: Adiabatic I and III
Isochoric II and IV
Direction of cycle

(b) Amount of gas-air mixture in the cylinder

$$n = \frac{p_1 V_1}{R T_1} = \frac{1.00 \times 10^5 \times 600 \times 10^{-6}}{8.31 \times (273 + 25)} = 0.0242 \text{ mol}$$

M1

Mass of gas-air mixture

$$m = 0.0242 \times 0.0288 = 6.97 \times 10^{-4} \text{ kg}$$

A1

C1

*C1 – correct conversion of V and T
(Answer is $m = 6.98 \times 10^{-4}$ kg if using unrounded value of n.)

(c) **(i)** Since $TV^{0.4} = k$, we can write

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{0.4}$$

or $$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{0.4}$$

M1

$$T_2 = (273 + 25) \times (7.00)^{0.4} = 649 \text{ K}$$

A1

*M1 – mark is awarded for correct relationship.

(ii) The fuel will **self-ignite before the cylinder completes the compression stroke** (ignition temperature < T_2). M1

The cylinder **pressure increases** tremendously while the piston is **still moving upward** can cause **piston/valve damage**. A1

(d) $Q_{II} = mc_v(T_3 - T_2)$

Rearranging, we obtain

$$T_3 = \frac{Q_{II}}{mc_v} + T_2$$ M1

$$= \frac{600}{6.97\times10^{-4}\times722} + 649 = 1841.4 \approx 1840 \text{ K}$$ A1

(e) **(i)** For process I,

$Q = 0$

$W_{\text{I, on mixture}} = U_2 - U_1$ B1

$= \frac{5}{2}nR(T_2 - T_1)$ M1

$= \frac{5}{2}\times0.0242\times8.31\times(649-298) = 176 \text{ J}$ A1

Note: work done on the petrol-air is positive.

(ii) For process III,

$W_{\text{III, by mixture}} = -(U_4 - U_3)$

$= -\frac{5}{2}nR(T_4 - T_3)$ M1

$= -\frac{5}{2}\times0.0242\times8.31\times(845-1841) = 501 \text{ J}$ A1

*Note: work done on the exhaust-air is negative.

(f) Since each complete cycle requires 2 revolutions of the crankshaft, there are 1500 cycles per min or 25 cycles per sec. B1

Therefore power of this engine

$P = 25\times(W_{\text{III, by mixture}} - W_{\text{I, on mixture}}) = 25\times(501-176) = 8125 \text{ W}$ A1

(g) Air is **denser** on a colder day so the **amount of fuel in the mixture is greater**. B1

Upon ignition, **more heat Q_{II} is produced** (assuming perfect combustion), resulting is a **greater net work done** and hence greater power. B1

6 **(a)** **(i)** Magnetic flux density of a magnetic field is the force per unit length that acts on a wire carrying unit current and lying at right angles to the magnetic field. B1

SI unit: tesla (T) B1

(ii) Magnetic flux through an area is the product of the area and the magnetic flux density that passes through the area perpendicularly. B1

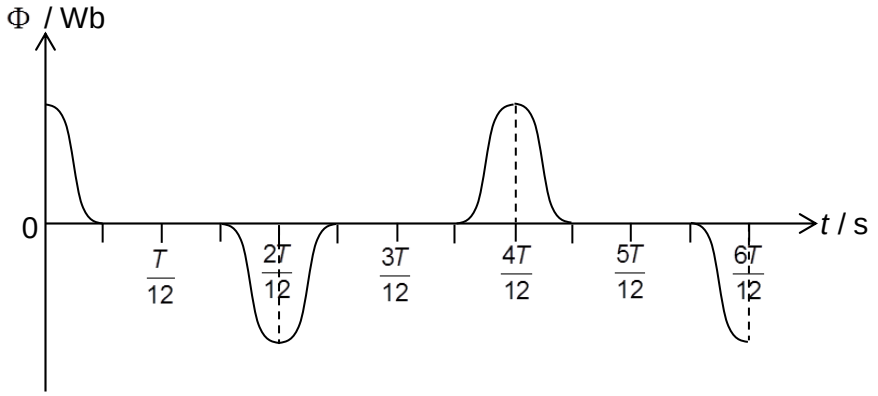
SI unit: Weber (Wb) B1

(b) **(i)** As the magnets in the rotating discs continuously approach and leave the coil, the magnetic flux density the coil is in changes / direction of the magnitude flux density changes due to the alternating magnetic poles. B1

This causes a change in the magnetic flux linkage of the coil. B1

By Faraday's law, there will be an induced e.m.f. across the coil.

(ii) **1.**



B1

2. When the magnets are in front of the coil at t = 0, the magnetic flux linkage of the coil is a maximum. As the magnets rotate away from the coil, the magnetic flux linkage will decrease to zero.

The magnetic flux linkage will increase again to a maximum when the neighbouring magnets approach the coil until they are in front of the coil and the magnetic flux linkage will decrease again as the magnets rotate away from the coil. B1

The sign of the magnetic flux linkage will alternate as the south and north poles of the magnets will alternately approach the coil. B1

Maximum flux linkage will occur every one-sixth of a period.

The induced E–t graph may be obtained from the negative of the gradient of the Φ–t graph ($E = -\frac{d\Phi}{dt}$). B1

(iii) Any two ways:
1. Increase the rate of rotation of the discs. B1
2. Use stronger magnets. B1
3. Place P and Q closer to each other.
4. Insert a soft iron core into the coil.

(iv) **1.**

$$f = \frac{50 \text{ rev}}{1 \text{ s}}$$

$$T = \frac{1}{f} = \frac{1}{50} = 0.020 \text{ s}$$ A1

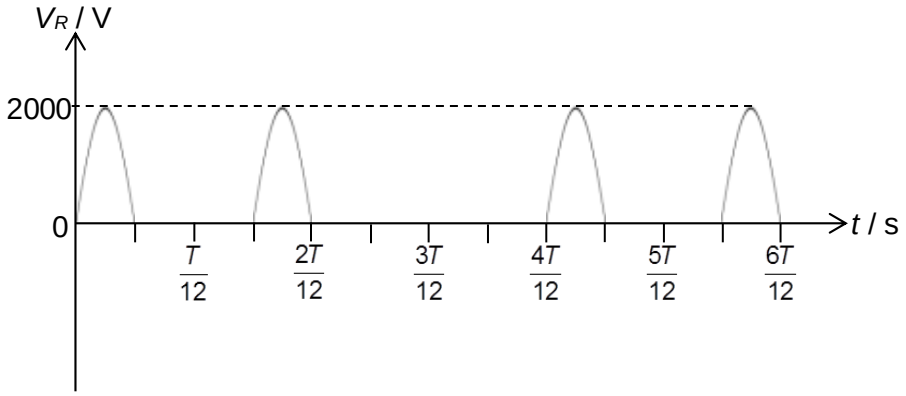
2.

$$V_s = \frac{N_s}{N_p} V_p$$

$$= \frac{800}{40}(100)$$

$$= 2000 \text{ V}$$ A1

3.



B1

4. There are 2 peaks for every $T/3$. Hence in one period, there are 6 peaks. M1

$$\text{r.m.s. voltage} = \sqrt{\frac{\left(2000^2/2\right)\left(T/24\right)(6)}{T}} = 707.1 = 707 \text{ V}$$ M1

OR

The pattern of 2 peaks repeats itself every $T/3$. M1

$$\text{r.m.s. voltage} = \sqrt{\frac{\left(2000^2/2\right)\left(T/24\right)(2)}{4T/12}} = 707.1 = 707 \text{ V}$$ M1

OR

The mean-square value for a full wave sinusoidal waveform has 24 peaks in one period. Since this waveform has 6 peaks in one period, its mean square value is ¼ of that for full wave. M1

$$\text{mean square voltage} = \left(\frac{v_0}{\sqrt{2}}\right)^2 \times \frac{1}{4}$$

$$\text{r.m.s. voltage} = \sqrt{\frac{{v_0}^2}{4\left(\sqrt{2}\right)^2}} = \frac{v_0}{2\sqrt{2}} = \frac{2000}{2\sqrt{2}} = 707.1 = 707 \text{ V}$$ M1

5.

$$P_m = \frac{{V_{r.m.s.}}^2}{R} = \frac{707^2}{200} = 2499 = 2500 \text{ W}$$ A1

(v) When the transformer is connected to the coil, a current flows in the coil.
By Lenz's law, the direction of this induced current in the coil will be such as to produce a magnetic field that opposes the magnetic field of the magnets in the discs. B1
This will result in magnetic forces that will create a torque that opposes the rotation of the rotating discs and cause the discs to rotate at a decreasing rate.
Thus an external torque that is equal and opposite to the opposing torque on each disc is required to keep the discs rotating at a constant rate. B1

OR

When the transformer is connected to the coil, a current flows in the coil.
By Lenz's law, the direction of this induced current in the coil will be such as to produce a magnetic field that opposes the magnetic field of the magnets in the discs. B1

This will result in magnetic forces that will create a torque that opposes the rotation of the rotating discs and cause the kinetic energy of the discs to decrease.
Thus an equal and opposite external torque is required to do work against the opposing torque to keep the discs rotating at a constant rate. B1

OR

When the transformer is connected to the coil, a current flows in the coil.
Mechanical energy of the rotating discs is converted to electrical energy in the coil. This causes the kinetic energy of the discs to decrease. B1
Thus an external torque is required such that the rate of work done by the external torque is equal to the rate of conversion of electrical energy, resulting in no change in the rotational kinetic energy of the discs. B1

7 (a) (i) n = 2 B1
Y = proton / hydrogen nucleus B1

(ii) As there are many more protons than deuterons in the Sun, the reaction of two deuterons reacting to form a helim-4 is much less likely to occur than the reaction of step II. B1

(iii) $\Delta m = \left(4 \times 1.007276 - 4.001506 - 2 \times 0.000585\right)\left(1.66 \times 10^{-27}\right)$
$= 4.387 \times 10^{-29}$ kg M1

$E = \Delta m c^2 = 4.387 \times 10^{-29} \times \left(3.00 \times 10^8\right)^2$ M1

$= 3.95 \times 10^{-12}$ J A1

(b) (i) Energy generated per second $= 1400 \times 4\pi \left(1.5 \times 10^{11}\right)^2$ M1

$= 3.96 \times 10^{26}$ W A1

(ii) 1. No. of reactions per second $= \dfrac{3.96 \times 10^{26}}{3.95 \times 10^{-12}} = 1.00 \times 10^{38}$ A1

2. No. of protons at present $= \dfrac{2 \times 10^{30}}{1.007276u} = 1.196 \times 10^{57}$ M1

time taken $= \dfrac{1.196 \times 10^{57}}{4(1.00 \times 10^{38})} = 2.99 \times 10^{18}$ s A1

(c) (i) It is the time taken for a sample of radioactive atoms to decay to half its original number. B1

(ii) ${}^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$ B1

(iii) 1. As radioactivity is a random process, the number of decays per unit time is subjected to statistical fluctuations. The error is especially significant when the number of decays is low. By measuring over ten minutes, a larger number of decays is recorded and the random error due to statistical fluctuations is less significant. B1 B1

2.

No. of carbon atoms in 33.3 g $= \dfrac{33.3}{12} \times 6.02 \times 10^{23}$ M1

$= 1.67 \times 10^{24}$

(shown)

No. of carbon-14 atoms at the beginning $= 1.67 \times 10^{24} \times \left(1 \times 10^{-12}\right)$ M1

$= 1.67 \times 10^{12}$

Initial activity $= \lambda N_o$

$= \dfrac{\ln 2}{5730 \times 365 \times 86400} \times 1.67 \times 10^{12}$

$= 6.41\ \text{s}^{-1}$ M1

By $A = A_o \left(\dfrac{1}{2}\right)^{t/T_{1/2}}$,

$\left(\dfrac{1}{2}\right)^{t/T_{1/2}} = \dfrac{0.4}{6.41} = 0.0624$ M1

$t = \left[\dfrac{\ln(0.0624)}{\ln(1/2)}\right] = 4.00 T_{1/2} = 22900$ years A1

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9646

PAPER 1

26 SEPTEMBER 2016

1 HOUR 15 MINUTES

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 the Answer Sheet.

*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 **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 **40**.

This document consists of **23** printed pages and **1** blank page.

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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm \omega \sqrt{{x_0}^2 - x^2}$

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, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_0 r}$

alternating current/voltage, $x = x_0 \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the one you consider to be correct.

1 Which of the following is not a correct unit for electric field strength?

A $N\ C^{-1}$

B $V\ m^{-1}$

C $kg\ m\ s^{-3}\ A^{-1}$

D $s^4\ A^2\ m^{-2}\ kg^{-1}$

2 Which pair includes a vector quantity and scalar quantity?

A velocity, moment

B electric current, pressure

C magnetic flux density, magnetic flux

D distance between 2 points, electric potential

3 In an experiment to determine the acceleration of free fall using a falling body, what would lead to a value that is larger than actual?

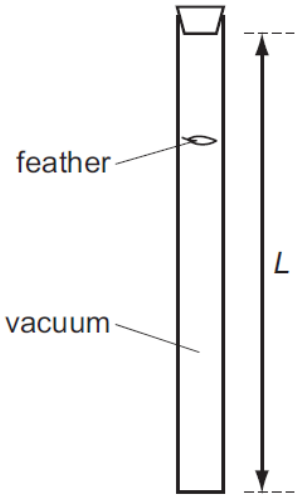
A presence of air resistance

B dimensions of the body are too large

C measured time longer than true time

D measured distance longer than true distance

4 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 long will the feather take to fall 0.50 *L* from the top of the tube?

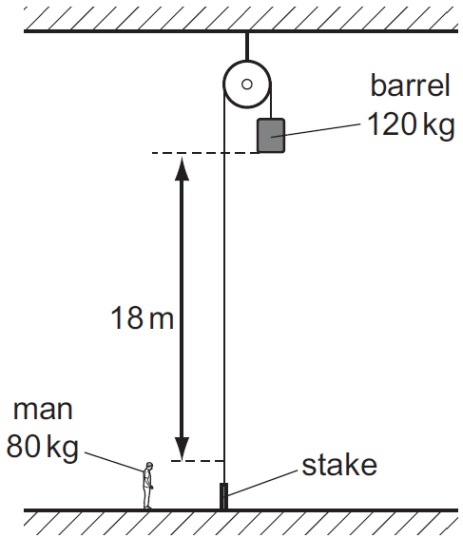
A 0.13 *T*

B 0.25 *T*

C 0.50 *T*

D 0.71 *T*

5 The diagram shows a barrel suspended from a frictionless pulley on a building. The rope supporting the barrel goes over the pulley and is secured to a stake at the bottom of the building.



A man stands close to the stake. The bottom of the barrel is 18 m above the man's head. The mass of the barrel is 120 kg and the mass of the man is 80 kg. The man keeps hold of the rope after untying it from the stake and is lifted upwards as the barrel falls.

What is the man's upward speed when his head is level with the bottom of the barrel?

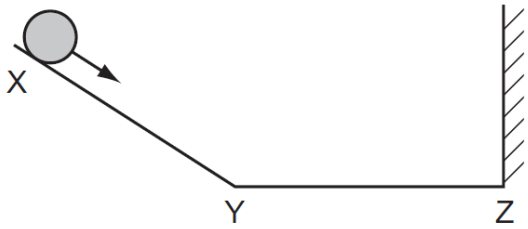
A 5.2 m s^{-1}

B 5.9 m s^{-1}

C 9.4 m s^{-1}

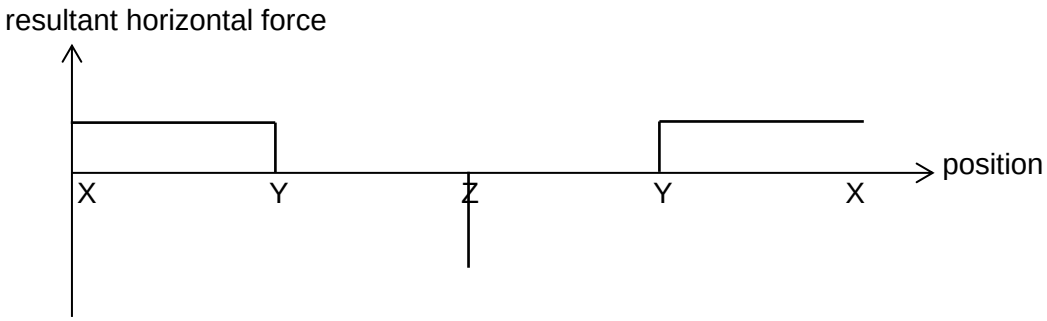
D 10 m s^{-1}

6 A ball is released from rest on a smooth slope XY.
It moves down the slope, along a smooth horizontal surface YZ and rebounds at Z.
Then it moves back to Y and comes to rest momentarily somewhere on XY.

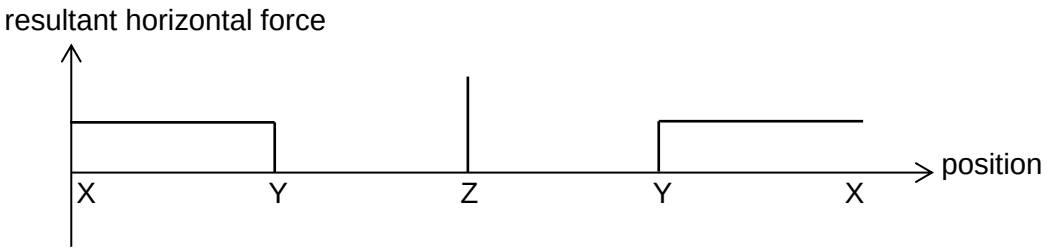


Which graph represents the resultant horizontal force on the ball?

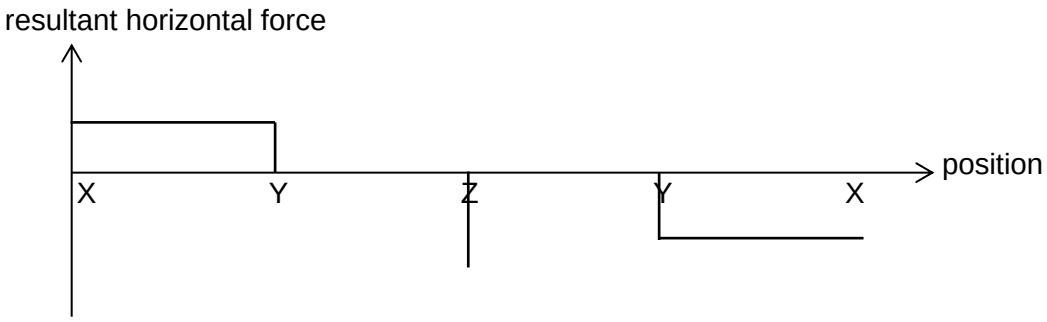
A



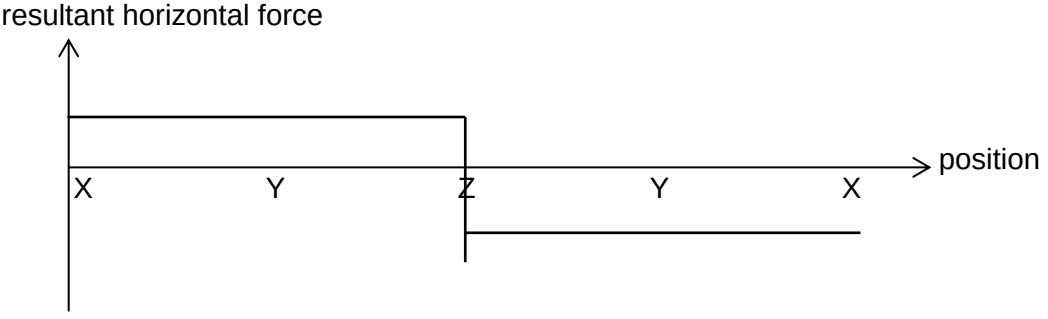
B



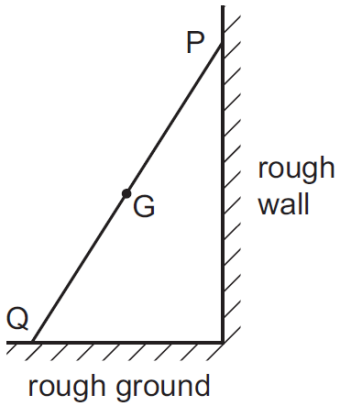
C



D



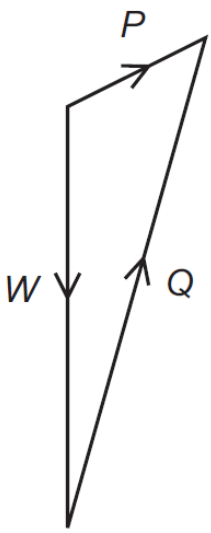
7 A ladder rests in equilibrium on rough ground against a rough wall.



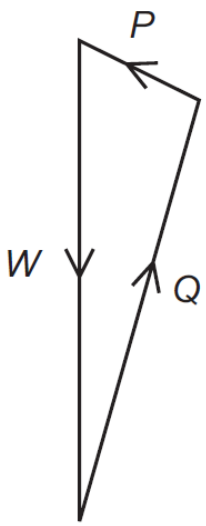
Its weight W acts through the centre of gravity G. Forces also act on the ladder at P and at Q. These forces are P and Q respectively.

Which vector triangle represents the forces on the ladder?

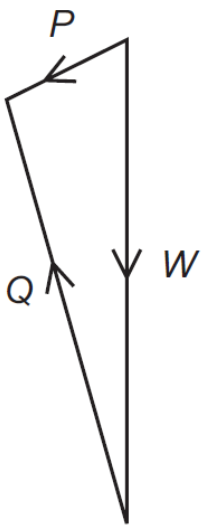
A



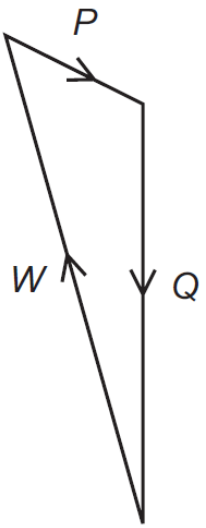
B



C



D



8 A load of 400 N is placed squarely onto a uniform cube of volume 0.729 m^3 floating in water.

What is the change in depth of the cube submerged in the water after the load and cube settle, given that the density of water is 1000 kg m^{-3}?

A 0.0503 m

B 0.0559 m

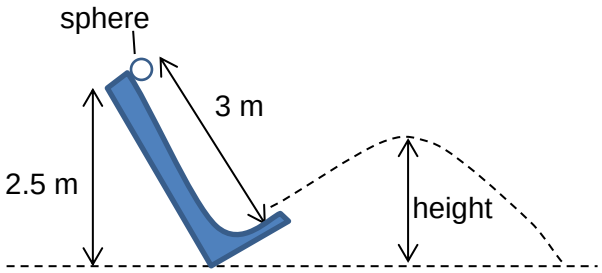
C 0.900 m

D There is insufficient information to calculate as the mass and density of the cube is not given.

9 A sphere is released from rest at the top of a smooth incline 3.0 m long and at a height of 2.5 m from the ground. When it reaches the end of the incline, it projects out and lands somewhere on the ground.

If there is no loss of mechanical energy (gravitational and kinetic energy), what is the maximum height it can reach before touching the ground?

Assume air resistance and friction are negligible.



A Less than 2.5 m

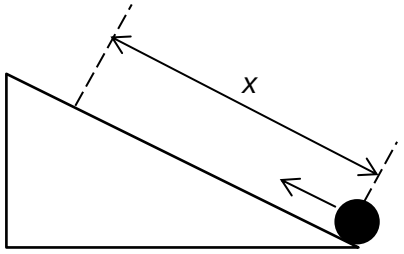
B 2.5 m

C Between 2.5 m and 3.0 m

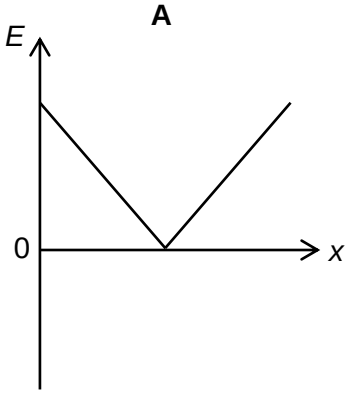
D 3.0 m

10 A small object placed at the bottom of a smooth slope is given a momentary force up the slope.

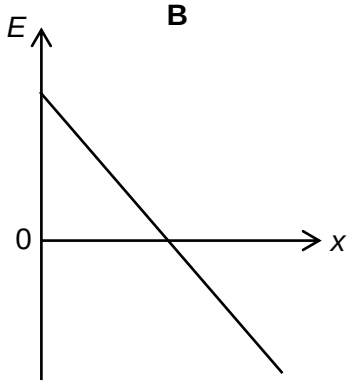
Which of the following shows the variation of its kinetic energy E with the distance x as it goes up and then down the slope?



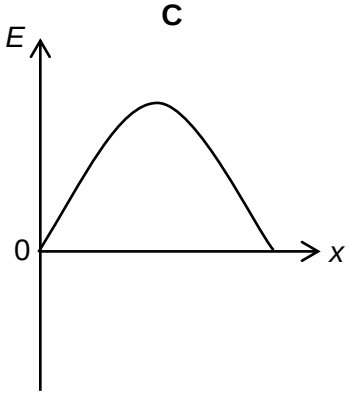
A



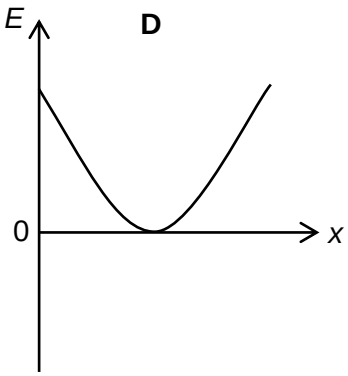
B



C



D



11 Which statement best explains why a coin flies off a rapidly rotating turntable?

A Centrifugal force acts on the coin and causes them to fly off.

B The outward force on the coin is greater than the centripetal force on it.

C The changing velocity causes the coin to not have a good grip on the turntable.

D The frictional force on the coin is insufficient to keep it moving in a circle round the turntable.

12 A radar tower 0.20 km tall is built at the equator on a hill of height 1.30 km.

As a result of the Earth's rotation, what is the difference in the speed between a man at the top of the tower and someone at the foot of the hill?

A zero

B 0.11 m s^{-1}

C 0.39 m s^{-1}

D More information needs to be provided before the question can be solved.

13 Two planets of mass m_1 and m_2 perform circular motion about their common centre of mass. 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?

A $\frac{m_1}{m_2} d$

B $\frac{m_2}{m_1} d$

C $\frac{m_1}{m_1 + m_2} d$

D $\frac{m_2}{m_1 + m_2} d$

14 In an experiment performed in deep space, sphere A of 20 kg and sphere B of 40 kg are released from rest with their centres 60 m apart. The spheres have equal diameters of 6.0 m. They accelerate toward each other due to their mutual gravitational attraction.

Ignoring all other possible gravitational forces in space, what is speed of sphere B just before they collide?

A 8.2×10^{-6} m s^{-1}

B 2.3×10^{-6} m s^{-1}

C 1.6×10^{-5} m s^{-1}

D 1.2×10^{-5} m s^{-1}

15 Which statement about internal energy is correct?

A At absolute zero, the internal energy of a system is zero.

B When the internal energy of a system is increased, its temperature always rises.

C The internal energy of a system cannot be increased without transfer of energy by heating.

D When two systems have the same internal energy, they may not be at the same temperature.

16 In metalworking, a hot iron bar at 400 °C is submerged into a container of water at 30 °C.

Quantity	Magnitude
mass of water	m_w
mass of iron bar	$5.0\, m_w$
specific heat capacity of water	c_w
specific heat capacity of bar	$0.10\, c_w$
specific latent heat of vaporisation of water	$540\, c_w$

Assuming that no heat is lost to the surroundings, when the bar and water have reached thermal equilibrium, what fraction of water has vaporised?

A zero

B 0.15

C 0.31

D 0.41

17 The restoring force by a spring on a mass placed on a horizontal, frictionless surface is given by the expression $F = -kx$.

Applying Newton's second law to the motion of the block along with the expression above, we obtain $a = -\frac{k}{m}x$.

Which of the expressions below gives the period for such an oscillating mass?

A $T = 2\pi\sqrt{\frac{m}{k}}$ **B** $T = 2\pi\sqrt{\frac{k}{m}}$ **C** $T = 4\pi\sqrt{\frac{m}{k}}$ **D** $T = 4\pi\sqrt{\frac{k}{m}}$

18 A particle is oscillating in simple harmonic motion with an amplitude of x_0. The kinetic energy of the particle is E_K and its potential energy is E_P.

What is the displacement of the particle when $E_K = E_P$?

A 0.250 x_0

B 0.333 x_0

C 0.500 x_0

D 0.707 x_0

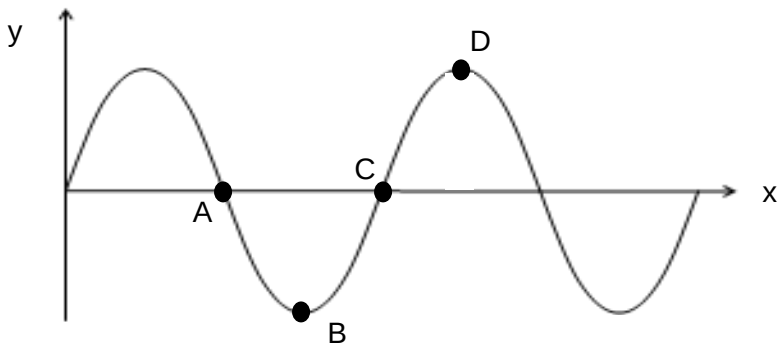
19 Given that the average solar intensity on Earth is 1300 W m^{-2}, what is the amount of solar radiation incident on Mars?

Earth's distance away from Sun:	150 million km
Mars' distance away from Sun:	230 million km
Earth's radius:	6400 km
Mars' radius:	3400 km

A 2.0×10^{10} W **B** 4.0×10^{10} W **C** 2.0×10^{16} W **D** 4.0×10^{16} W

20 The figure below shows variation of the distance x along a sound wave of displacement y of particles in the wave.

Given that the wave is moving to the right at the instant shown, and that displacement to the right is defined as positive, which of the points shows a region of compression?

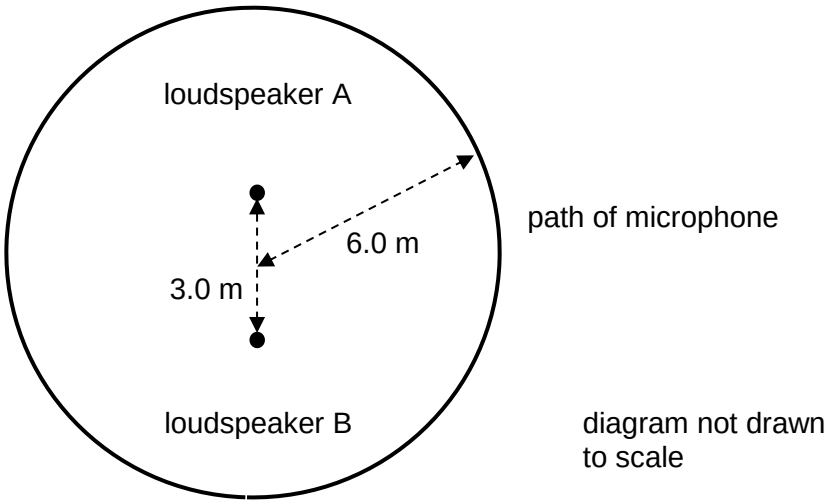


21 Two plane-polarised waves with amplitude x_0 have their planes of polarization perpendicular to each other.

What is the difference in amplitudes of the resultant waves when they meet in phase and out of phase?

A zero **B** 0.707 x_0 **C** x_0 **D** 1.41 x_0

22 Two small and identical loudspeakers are placed 3.0 m apart. The loudspeakers are in phase and emit sound of wavelength 1.0 m uniformly in all directions.

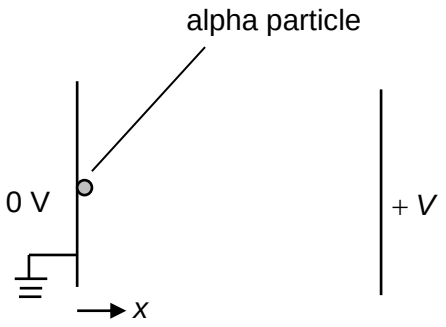


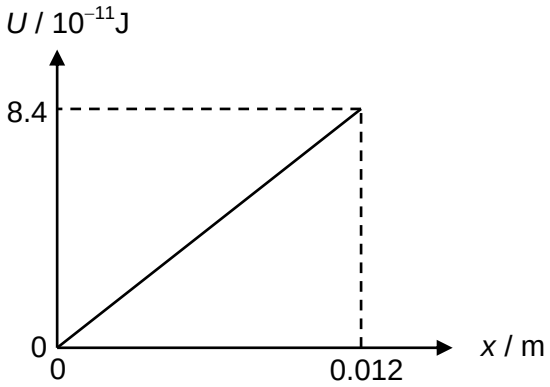
A microphone is moved in a circular path for one complete round of radius 6.0 m.

How many maxima will be detected?

A 8 **B** 10 **C** 12 **D** 14

23 The electrical potential energy U of an alpha particle in a uniform electric field between two charged parallel plates 0.012 m apart varies with displacement x from the earthed plate as shown in the diagram.





What is the force on the alpha particle by the electric field?

A 2.2×10^{10} N

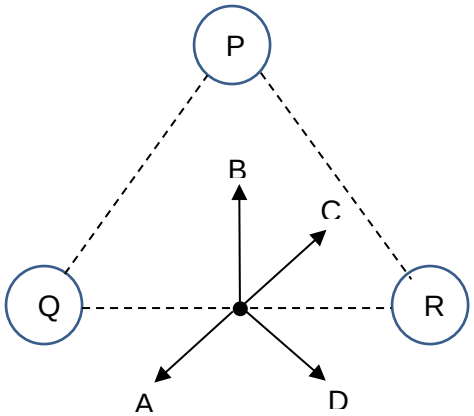
B 7.0×10^{-9} N

C -7.0×10^{-9} N

D -2.2×10^{10} N

24 Three identical spheres, P, Q and R, are fixed at equal distances to each other as shown below. The charges of P, Q and R are 1.0 C, – 0.50 C and 0.50 C respectively.

If an electron is placed mid-point between Q and R, what is the direction of the electric force acting on the electron?



25 Which of the following statements is true regarding the variation of electrical resistivity of diodes with temperature?

A The scattering of electrons by lattice ions is increased by temperature, so the increase in free electrons is not significant enough to cause a decrease in electrical resistivity.

B Electrical resistivity decreases with temperature as more free electrons are available for conduction.

C At constant temperature, the electrical resistivity can be decreased by applying a greater potential difference.

D As temperature decreases, electrical resistivity decreases since mean time between collisions of electrons with lattice ions increases.

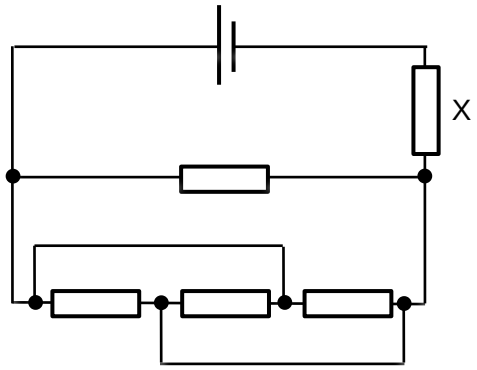
26 Two wires A and B of the same material are connected in parallel to a battery. The length of A is half that of B and it has half the radius of B.

What fraction of the total current passes through A?

A 0.33 **B** 0.50 **C** 0.67 **D** 0.75

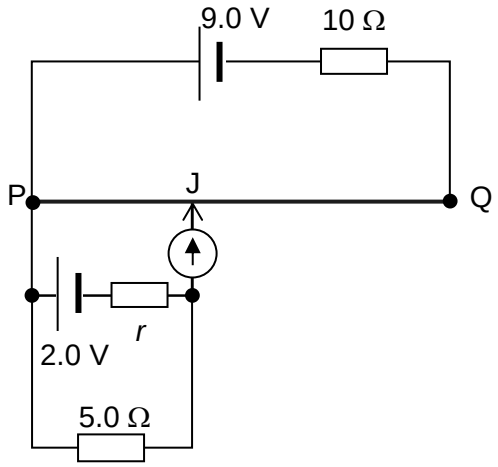
27 Five identical resistors are connected as shown in the circuit.

If the power dissipated by X is 2.0 W, what is the total power supplied by the battery?



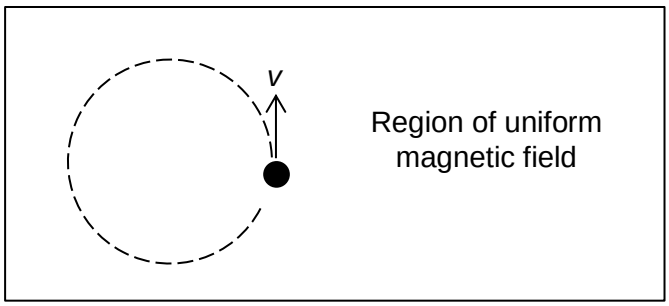
A 2.5 W **B** 3.5 W **C** 7.5 W **D** 10 W

28 Given PQ = 1.0 m and has resistance 10 Ω, balance length = 20 cm, what is the resistance *r* ?



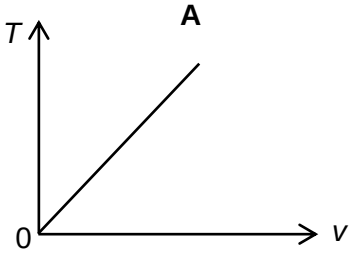
A zero **B** 2.0 Ω **C** 6.1 Ω **D** 11 Ω

29 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.

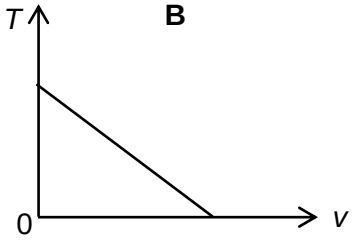


Which of the following represents the variation of its period T with v ?

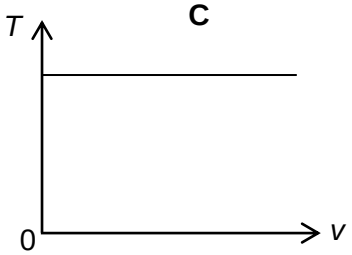
A



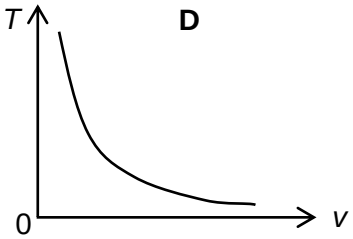
B



C

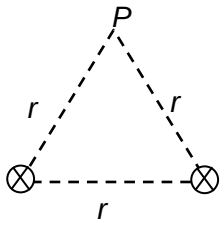


D



30 Two long straight parallel conductors, each carrying a current I, are separated by a distance r. The magnetic flux density B at a distance r from a conductor carrying a current I is given by $B = \frac{\mu_0 I}{2\pi r}$.

What is the magnetic flux density at point P, at the same distance r from each conductor, as shown below?



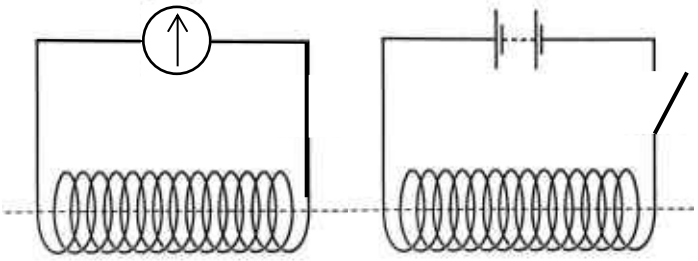
A $\frac{\mu_0 I}{2\pi r}$ to the right

B $\frac{\sqrt{3}\mu_0 I}{2\pi r}$ to the right

C $\frac{\mu_0 I}{\sqrt{2}\pi r}$ to the left

D $\frac{\sqrt{3}\mu_0 I}{\pi r}$ to the left

31 Two solenoids, one connected to a galvanometer and another to an e.m.f. source and switch are placed with the open ends of the coils facing each other as shown.



When the switch is closed, the maximum movement of the meter needle is 10 units to the right.

With the switch still closed, the solenoids are brought closer to each other. When the switch is opened, what is the maximum movement of the meter needle?

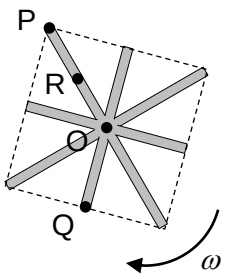
A less than 10 units to the left

B less than 10 units to the right

C more than 10 units to the left

D more than 10 units to the right

32 An eight-pointed figure, cut out from a square aluminium sheet, rotates about its centre O at a constant rate of ω. It is placed in a magnetic field perpendicular to its surface. Steady electromotive forces (e.m.f.) are generated between the centre O and the tips. P is at the tip of the longer branch and Q is at the tip of the shorter branch. R is the midpoint of OP.



Between which two points is the potential difference the smallest?

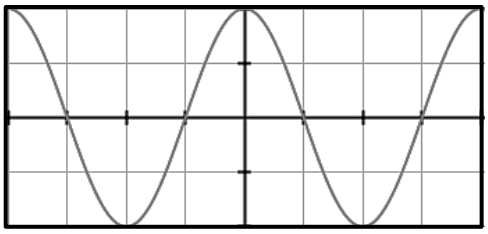
A OQ

B PQ

C QR

D PR

33 A cathode-ray oscilloscope screen with grid of 1 cm squares displays an alternating voltage waveform. The settings of the oscilloscope are: gain = 1.0 V cm^{-1}, time-base = 2.0 ms cm^{-1}.



The alternating voltage is across a resistor of resistance 10 Ω. The current I through the resistor at time t, measured in seconds, is

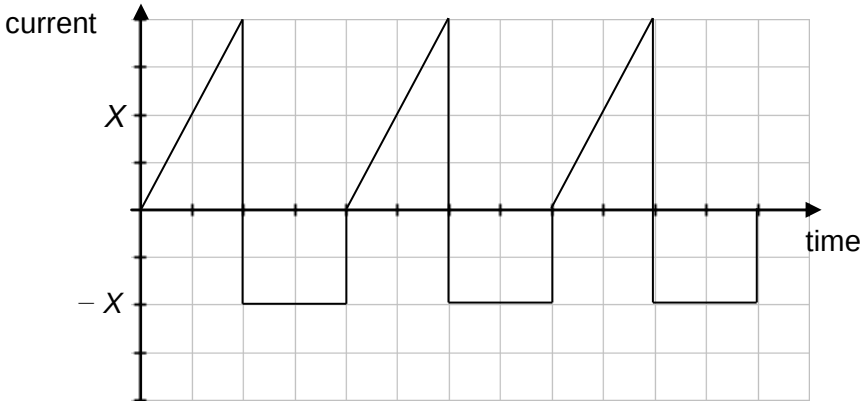
A 0.20 cos 0.785 t

B 0.20 cos 785 t

C 0.14 cos 0.785 t

D 0.14 cos 785 t

34 The graph shows an alternating current waveform.



What is the best approximation of its root-mean-square value I_{rms}?

A $I_{rms} \leq X$

B $X < I_{rms} < 1.22\,X$

C $1.22\,X \leq I_{rms} < 1.50\,X$

D $I_{rms} \geq 1.50\,X$

35 An atom absorbs a photon of wavelength 380 nm and then re-emits the energy through two electronic transitions such that the atom returns its original energy level. If one of the emitted photon has a wavelength of 650 nm, what is the type of radiation that could represent the other emitted photon?

A ultraviolet ray **B** infrared **C** red light **D** violet light

36 A 3.0 eV electrons encounters a potential barrier of width 0.40 nm with height 5.4 eV. The probability of a 3.0 eV electron tunnelling through the barrier is 0.0006.

If the barrier height is kept constant, what is the barrier width in order for a 3.0 eV electron to increase the probability of transmission by five times?

A 0.08 nm

B 0.10 nm

C 0.30 nm

D 0.50 nm

37 On most laser pointers, there is a warning label to inform users to avoid direct eye exposure even though the visible light comes from a low power source as shown in the diagram.



Which of the following explanations could be the possible reason why it is not advisable to look directly at visible light from laser pointers?

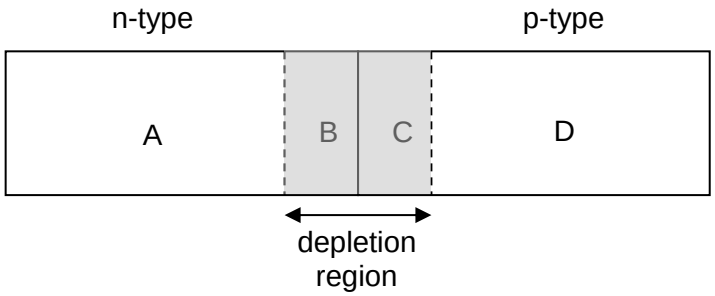
A High frequency of the visible light.

B High energy photons from the light source.

C Visible light has wide range of wavelengths.

D High number of photons incident on the eyes per unit time.

38 A model of a semiconductor diode is shown in the diagram.



Which of the following statements is correct?

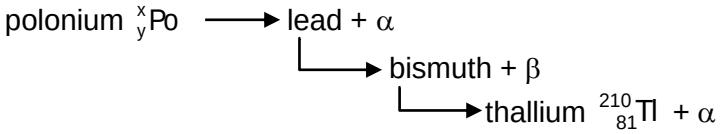
A Negative ions are found in region C.

B During reverse-biased, both region C and region D decreases.

C During forward-biased, holes will flow from region A to region D.

D Depletion region is formed when Group III atoms in region B accepts holes from region C.

39 A nucleus of polonium ${}^{x}_{y}\text{Po}$ decays to thallium ${}^{210}_{81}\text{Tl}$ by a sequence of particle emissions.



How many neutrons are there in a nucleus of ${}^{x}_{y}\text{Po}$?

A 84 **B** 86 **C** 132 **D** 134

40 A detector of ionising radiation gives a background count rate of 28 per minute. Samples of two radioactive nuclides, X and Y, are individually measured by the detector and each sample gives the same reading of 508 counts per minute. X has a half-life of 4 months and Y a half-life of 3 months. The samples are mixed together.

Assuming no change in background radiation levels, what will be the reading of the mixture after one year?

A 88

B 90

C 95

D 118

END OF PAPER

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9646

PAPER 2

15 SEPTEMBER 2016

1 HOUR 45 MINUTES

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*.

FOR EXAMINERS' USE	
1	/4
2	/10
3	/5
4	/8
5	/9
6	/6
7	/18
8	/12
Deduction	
TOTAL	/72

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

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

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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$v = \pm\omega\sqrt{(x_0^2 - x^2)}$

mean kinetic energy of a molecule of an ideal gas, $E = \frac{3}{2}kT$

resistors in series, $R = R_1 + R_2 + \ldots$

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, $x = x_0 \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

[Turn over

Answer **all** questions in the spaces provided.

1 The resistance X of an unknown resistor is measured by finding the potential difference across it and the current through it, using the circuit shown in Fig. 1.1.

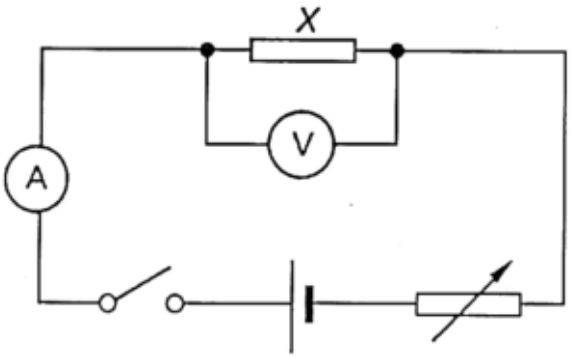


Fig. 1.1

(a) The variable resistor is adjusted and the potential difference across the unknown resistor and current through it are recorded.

Voltage V : 5.00 ± 0.03 V
Current I : 2.7 ± 0.2 mA

Using the values of V and I, find the resistance X of the resistor and express it with its associated uncertainty to the appropriate number of significant figures.

$X \pm \Delta X$ = ……Ω [2]

(b) When an experiment like this is performed, rather than taking an average, it is common practice to adjust the variable resistor so as to provide several pairs of values of potential difference and current. These values are then plotted on a graph, from which the resistance can then be deduced.

State two advantages of this procedure compared with the determination of X from a single pair of readings as in **(a)** above.

(1) ……

……

(2) ……

…… [2]

2 **(a)** State Newton's third law of motion.

……...

……...

……... [2]

(b) Two spheres approach one another along a line joining their centres, as illustrated in Fig. 2.1.

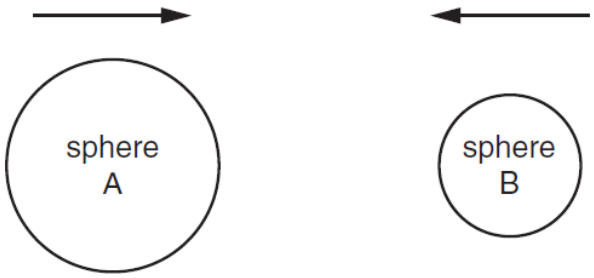


Fig. 2.1

When they collide, the average force acting on sphere A is F_A and the average force acting on sphere B is F_B.

The forces act for time t_A on sphere A and time t_B on sphere B.

Show that the change in momentum of sphere A is equal in magnitude and opposite in direction to the change in momentum of sphere B.

[2]

[Turn over

(c) For the spheres in **(b)**, the variation with time of the momentum of sphere A before, during and after the collision with sphere B is shown in Fig. 2.2.

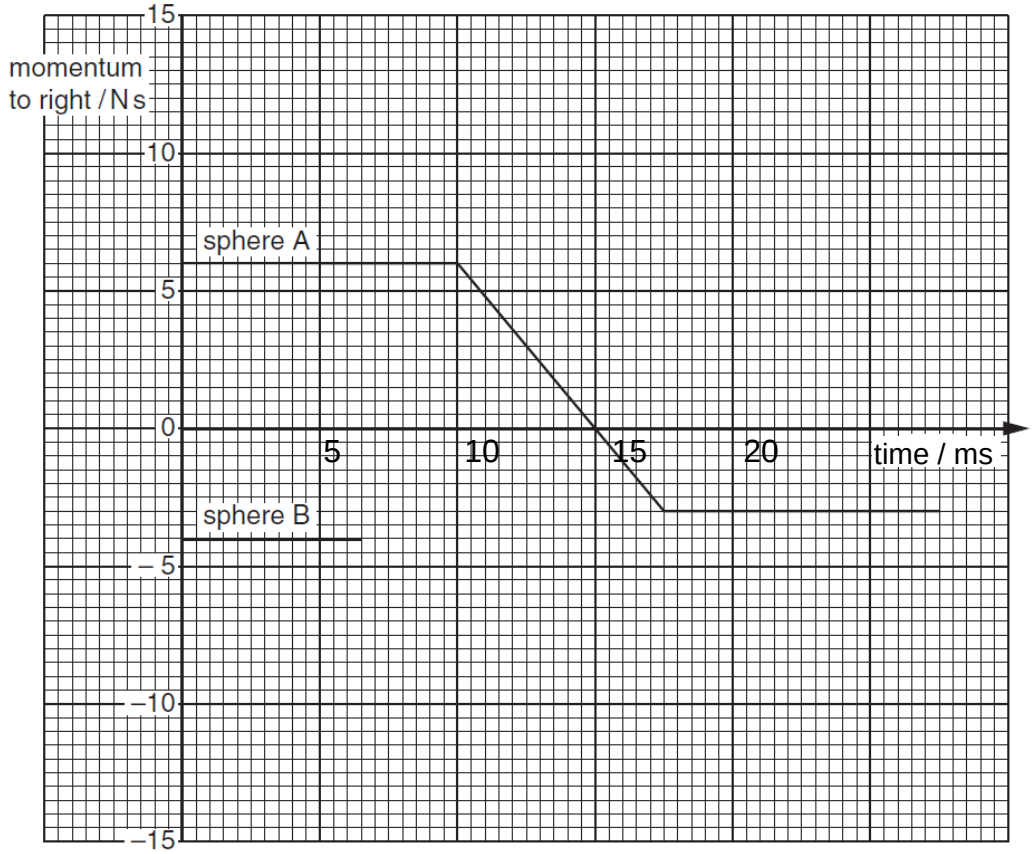


Fig. 2.2

(i) The momentum of sphere B before the collision is also shown on Fig. 2.2.

Complete Fig. 2.2 to show the variation with time of the momentum of sphere B during and after the collision with sphere A. [3]

(ii) Using Fig. 2.2, deduce the force exerted on sphere B.

magnitude of force = …….. N

direction of force on sphere B = …… [3]

3 A single bead can slide with negligible friction on a wire that is bent into a circular loop of radius 20.0 cm as seen in Fig. 3.1. The circle is always in a vertical plane and rotates steadily about its vertical axis with a period of 0.75 s.

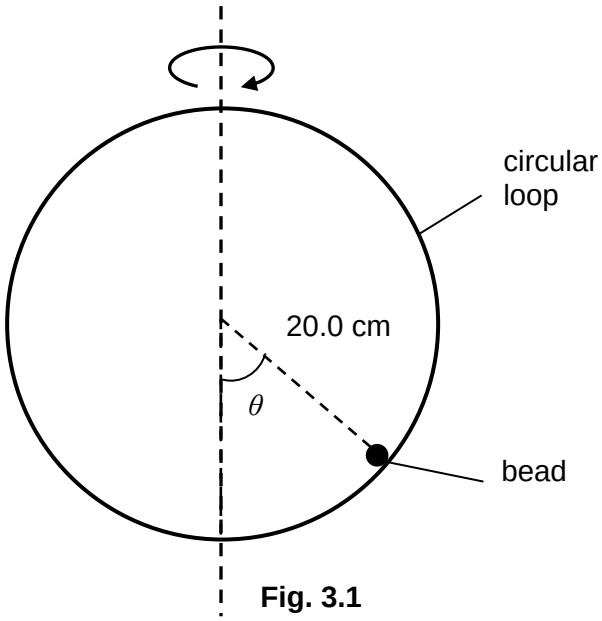


Fig. 3.1

There are two possible positions that the bead can remain motionless when the circle is rotating, at the bottom of the circle or at an angle θ relative to the vertical axis as shown in Fig. 3.1.

(a) Draw and label on Fig. 3.1, the forces acting on the bead when it is in the second position. Include the resultant force(s) on the bead using dotted lines. [1]

(b) By considering the forces on the bead, calculate θ.

θ = …….° [2]

(c) Hence or otherwise, explain what will happen to θ if the circle is rotating at a slower rate.

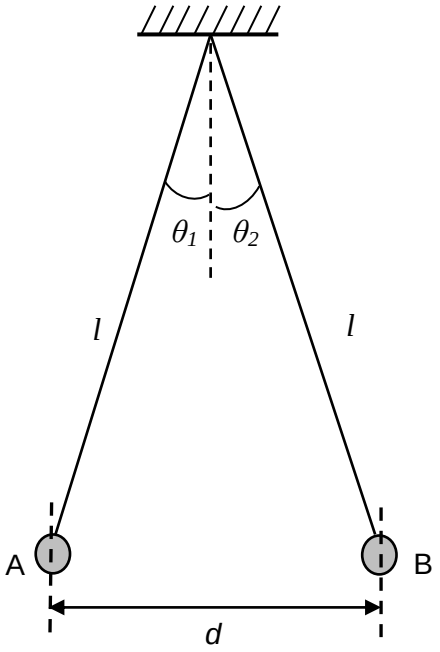
……

……

…… [2]

[Turn over

4 Spheres A and B are hung from light strings of length l as shown in Fig. 4.1. Each sphere has the same mass *m* and positive charge *q* and they may be treated as point charges.



not drawn to scale

Fig. 4.1

(a) Assuming θ_1 *and* θ_2 are equal as θ, show that if the angle θ is small, the equilibrium separation *d* between the centre of the spheres is

$$d = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg} \right)^{\frac{1}{3}}$$

(Hint: If θ is small, you may assume tan θ = sin θ)

[3]

(b) Given that m is 20 g, l is 18 cm and q is 12 nC, calculate d.

d = ... m [1]

(c) **(i)** The charge on sphere A is now doubled and the charge on sphere B is halved.

State and explain whether d, θ_1 and θ_2 will be affected.

.....

.....

..... [2]

(ii) On Fig. 4.2, draw electric field lines to represent the electric field in the region between A and B for the charge configuration in **(c)(i)**.



Fig. 4.2 [2]

[Turn over

5 An electron enters a region R perpendicularly to a uniform magnetic field which is directed into the plane of the paper. A uniform electric field is directed downwards as shown in Fig. 5.1.

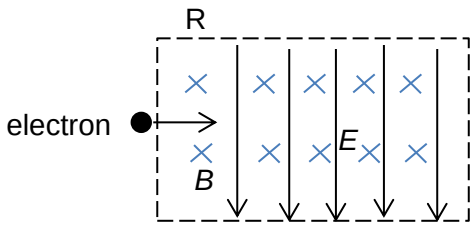
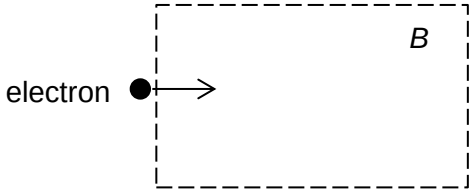


Fig. 5.1

The magnetic flux density *B* of the magnetic field and electric field strength *E* are adjusted such that the electron emerges undeviated.

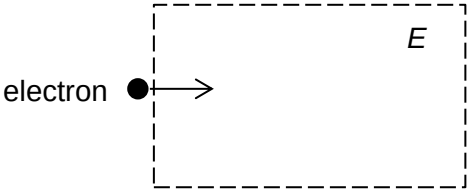
(a) Sketch and describe the path of the electron when

(i) only the magnetic field is turned on,



……

(ii) only the electric field is turned on.



…… [2]

(b) When the electric field is turned off and a magnetic field of constant flux density B is maintained, the electron moves in a circular path of radius 1.2 cm with a speed of 1.8×10^8 m s^{-1}.

Calculate the magnitude of the electric field strength E such that the electron will emerge undeviated when the electric field is turned on.

E = ... V m^{-1} [3]

(c) Describe the path of the following particles when they are projected into region R with both E and B of the same magnitude as **(b)** turned on.

(i) A proton with a speed of 1.8×10^8 m s^{-1}.

..... [1]

(ii) An alpha particle with a speed of 1.8×10^8 m s^{-1}.

..... [1]

(iii) An electron with a speed of 0.50×10^8 m s^{-1}.

..... [1]

(d) Sketch the path of an electron that is projected at an angle into region R, with B directed into paper and E turned off as shown in Fig. 5.2.

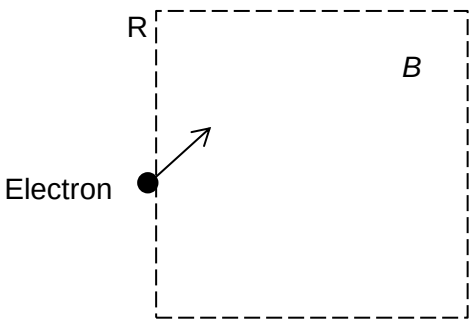


Fig. 5.2 [1]

[Turn over

6 **(a)** One of the functions of a diode is as a rectifier, allowing current to pass in single direction and opposing current in the opposite direction. This effect can be achieved using p-n junctions made of semiconductors.

A p-n junction is formed when n-type and p-type materials are joined as shown in Fig. 6.1.



Fig. 6.1

Explain how a p-n junction acts as a rectifier for an alternating current. You may draw a diagram if you wish.

……

……

……

……

……

……

…….. [3]

(b) Using band theory of conduction, explain how the resistance varies with an increase in temperature for an intrinsic semiconductor and a metal.

intrinsic semiconductor: ……

……

……

metal: ……

……

…….. [3]

7 In the design of electrical transformers, one of the key problems is power losses during operation. Much of the cost of transformers goes into mitigating the different sources of power loss. Two sources of power loss are “copper loss” due to the resistance of the wire windings and “core loss” which includes magnetic hysteresis and induced currents in the core linking the primary and secondary windings.

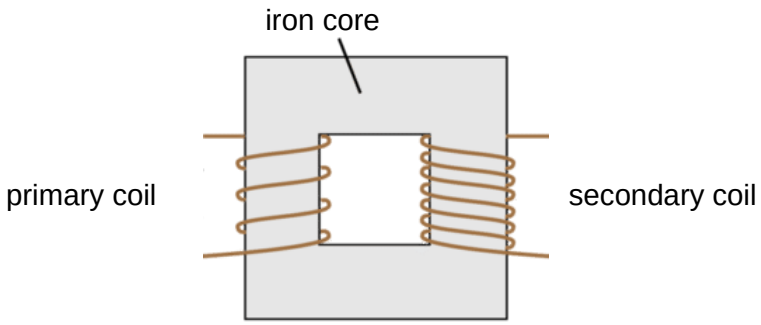


Fig. 7.1

To appreciate the power loss due to magnetic hysteresis, it is important to distinguish between the magnetic flux density B in the core and the magnetic field strength H due to current in the coil, which are related by the expression

$$B = \mu H$$

where μ is the permeability of the material of the core, and is the ratio of magnetic flux density in the material to an applied magnetic field strength.

(a) Fig. 7.2 shows part of a typical magnetic hysteresis graph of an iron core. The graph shows the variation of the magnetic flux density in the core with increasing (curve X) and decreasing (curve Y) magnetic field strength applied at the primary coil.

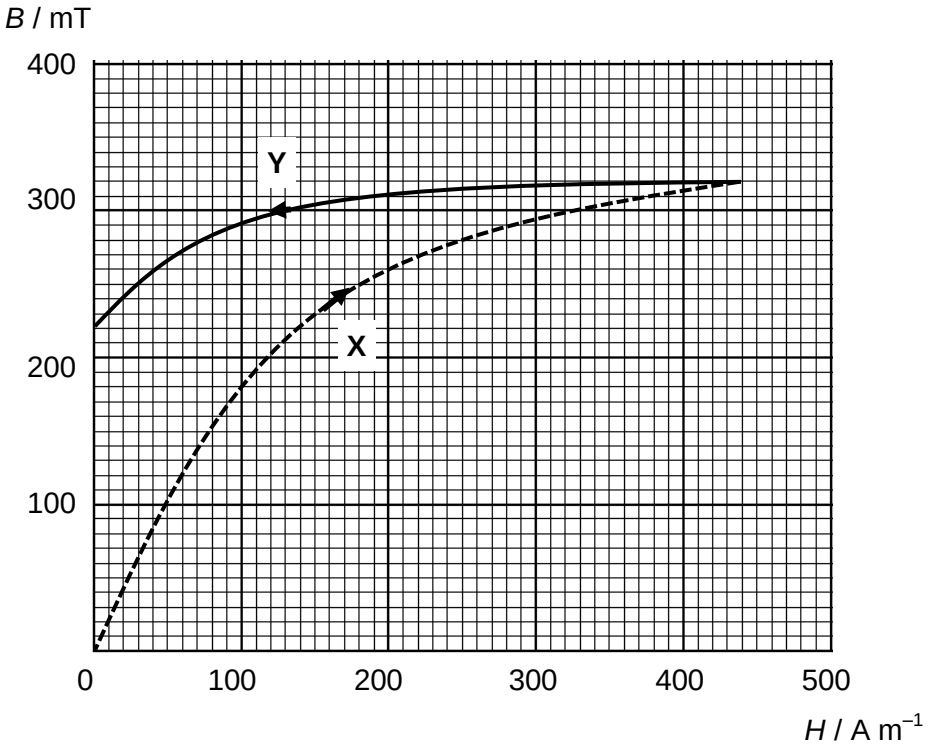


Fig. 7.2

[Turn over

(i) Using Fig. 7.2, explain whether the permeability of iron μ increases or decreases with the change in magnetic flux density in the core.

……

……

……... [1]

(ii) In a transformer, the iron core with a uniform cross sectional area of 0.090 m^2 is magnetised by an alternating current (a.c.) of 50 Hz in the primary coil. Under these conditions, the magnetic flux density in the core varies as shown in Fig. 7.2. Curve Y shows the demagnetization of the core in one-quarter of the a.c. cycle. The secondary coil of the transformer has 40 000 turns tightly wound around the core.

Calculate the change in magnetic flux linkage Φ in the secondary coil when the magnetic field strength H decreases to zero from the maximum value along curve Y.

change in magnetic flux linkage = ……. Wb [2]

(iii) Hence, calculate the average induced e.m.f. in the secondary coil during this quarter of an a.c. cycle.

induced e.m.f. in secondary coil = ……. V [2]

(b) The transformer is tested at a power station. An a.c. of frequency 50 Hz is applied to the primary coil. The average power loss per cycle of a.c. due to magnetic hysteresis P_h is measured while varying the maximum magnetic flux density in the core B_{max}. The variation with B_{max} of P_h is shown in Fig. 7.3.

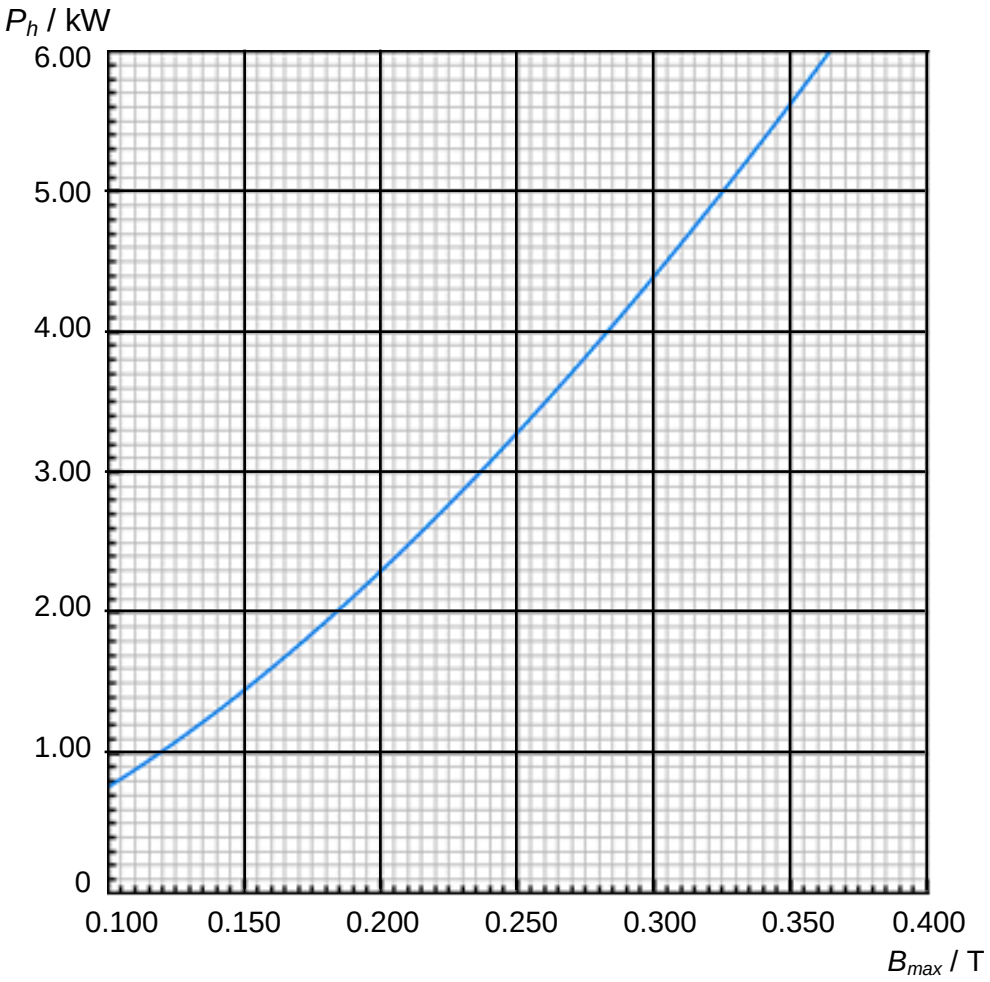


Fig. 7.3

It is thought that the average power loss per cycle of a.c. due to hysteresis P_h in the transformer iron core varies with a.c. frequency f and maximum magnetic flux density B_{max} in the core according to the expression

$$P_h = K_h f (B_{max})^n$$

where K_h is the effective hysteresis constant and n is a constant.

[Turn over

Fig 7.4 shows some of the data from Fig. 7.3 for B_{max} and P_h.

B_{max} / T	P_h / kW	lg (B_{max} / T)	lg (P_h / W)
0.100	0.751	–1.000	2.876
0.150	1.49	–0.824	3.173
0.200	2.26	–0.699	3.354
0.250			
0.300	4.39	–0.523	3.642
0.350	5.64	–0.456	3.751
0.400	6.04	–0.398	3.781

Fig. 7.4

Some of the data of Fig. 7.4 is plotted in Fig. 7.5.

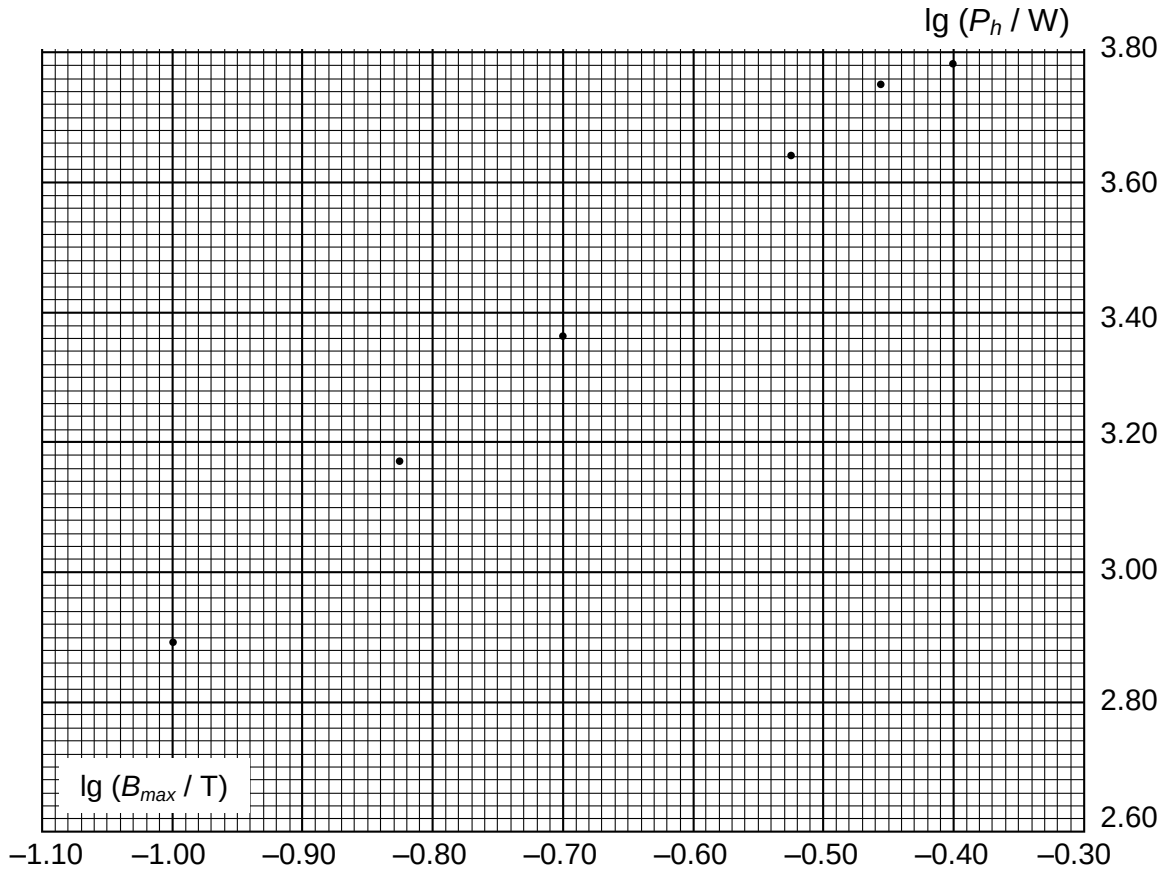


Fig. 7.5

(i) Using Fig. 7.3, complete the table in Fig. 7.4 and plot on Fig. 7.5 using your data for B_{max} = 0.250 T. [2]

(ii) On Fig. 7.5, draw a line of best fit for the points and use it to determine the constants n and K_h. Explain your working.

n = …….

K_h = ……. [4]

(iv) The test is repeated with the frequency of a.c. reduced to 25 Hz.

On Fig. 7.5, draw a second graph to represent the variation with B_{max} of P_h for the lower frequency.

[2]

[Turn over

(c) At the power station, the same transformer in **(b)** is now used to step up voltage for transmission as shown in Fig. 7.6. The primary coil has 200 turns and the secondary coil has 40 000 turns. The generator connected to the primary coil supplies an alternating 4 500 V peak voltage at 50 Hz to the transformer. The peak current in the primary coil is measured to be 10 A, and the maximum magnetic flux density in the core is 0.20 T.

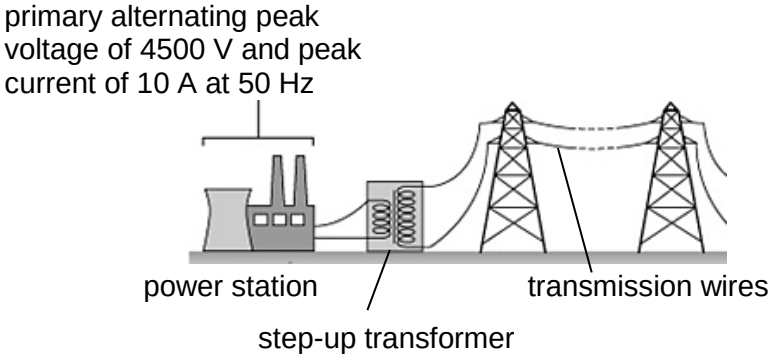


Fig. 7.6

(i) Using Fig. 7.3 to account for average power loss due to magnetic hysteresis in the core, calculate the efficiency of the transformer when running under these conditions.

efficiency = ……. [2]

(ii) Hence, calculate the average power loss in the 50 km long transmission wires of resistance 20 Ω connected to the secondary coil.

power loss = …….. W [2]

(iii) Suggest and explain whether your answer in **(c)(i)** is an underestimate or overestimate of the efficiency of the transformer.

……

……... [1]

8 Photoelectric cells, sometimes simply known as photocells, are devices that generate an e.m.f. when light falls on them. Their uses are varied. For example, in digital cameras, photocells are used to indicate the amount of light reaching the lens, thus helping the photographer decide on what shutter speed and aperture to use when taking the perfect shot.

The absorption coefficient of material determines how far into a material that light of a particular wavelength can penetrate before it is totally absorbed.

The absorption coefficient of glass may be investigated by placing various thickness of glass between a photocell and a light source.

The absorption coefficient is thought to depend on the e.m.f. E generated by the photocell by the equation

$$E = E_0 \, e^{-\alpha n t}$$

where α is the absorption coefficient of glass, n is the number of identical sheets of glass, t is the thickness of one sheet of glass and E_0 is the e.m.f. for $n = 0$.

Design an experiment to determine the absorption coefficient of glass.

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 absorption coefficient is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

[Turn over

For Examiner's Use

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For Examiner's Use

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RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATIONS II

H2 PHYSICS 9646

PAPER 3
22 SEPTEMBER 2016

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.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

FOR EXAMINERS' USE	
Section A	
1	/5
2	/6
3	/10
4	/7
5	/5
6	/7
Section B	
7	/20
8	/20
9	/20
Deduction	
TOTAL	/80

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

This document consists of **25** printed pages and **1** blank page.

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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$v = \pm\omega\sqrt{(x_0^2 - x^2)}$

mean kinetic energy of a molecule of an ideal gas, $E = \frac{3}{2}kT$

resistors in series, $R = R_1 + R_2 + \ldots$

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, $x = x_0 \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

[Turn over

Section A (40 marks)

Answer **all** the questions in the spaces provided.

1 While walking, Mr Ng's foot is momentarily in contact with the ground as shown in Fig. 1.1 and assumed to be in static equilibrium at that moment. *N* is the normal reaction force from the ground on the foot, *P* the force exerted on the ankle and *T* the tension in the Achilles' tendon.

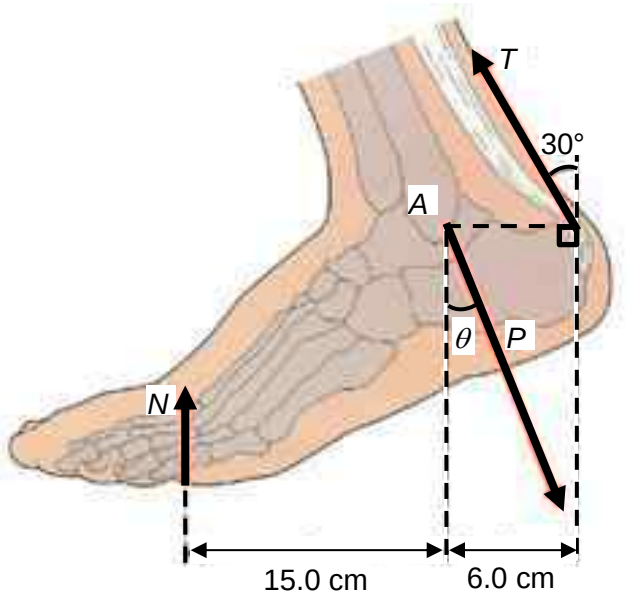


Fig. 1.1

(a) Given that Mr Ng has a mass of 65 kg and exerts a force equal to his weight on the ground at that instant, calculate the tension *T*. You may assume the mass of the foot to be negligible.

T = ... N [2]

(b) Hence or otherwise, calculate the angle θ.

θ = ... ° [3]

2 To estimate the frictional force acting on a truck, a driver puts his truck at the neutral gear (not stepping on the accelerator nor applying any brakes) while moving on a level road. He finds that the speed slows down from 24 km h^{-1} to 18 km h^{-1} over a distance of 10.5 m. The truck is of mass 1500 kg.

(a) **(i)** Show that the frictional force acting on the truck travelling on the level road is 1400 N.

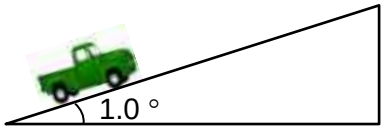
[1]

(ii) Hence or otherwise, determine the power developed by the truck's engine when it is travelling at a constant speed of 12 m s^{-1} on the level road. The frictional force can be assumed to be constant.

power = ... W [2]

[Turn over

(b) The truck then moves up a gentle slope of 1.0 ° as shown in Fig. 2.1. The frictional force acting on the truck along the slope is 800 N.



Not to scale

Fig. 2.1

Applying the same power from the engine as **(a)(ii)**, determine the maximum speed that the truck can attain up the slope.

speed = …….. m s^{-1} [3]

3 A geostationary satellite of mass 100 kg is in circular orbit around the centre of Earth. The Earth has radius 6.4 × 10^6 m.

(a) State what is meant by a *geostationary* satellite.

……

…….. [1]

(b) Show that the angular velocity of the satellite is 7.27 × 10^{-5} rad s^{-1}.

[1]

(c) Calculate the radius of the satellite's orbit around the centre of Earth.

radius = …….. km [3]

(d) An astronaut in the satellite experiences 'weightlessness' even though he is orbiting around the Earth. Explain why the astronaut seems to be weightless.

..……

..……

..…….. [2]

(e) The radius of the orbit of the satellite is increased after the satellite is hit by space debris. State and explain the effect on the potential energy and kinetic energy of the satellite in the new orbit.

..……

..……

..…….. [2]

(f) A research scientist decides to launch a replacement geostationary satellite. Suggest a location on Earth and the direction to launch the satellite to minimise the energy required.

..……

..…….. [1]

[Turn over

4 An ideal monatomic gas in a container of volume 0.40 m^3 at atmospheric pressure of 101 kPa undergoes three processes as shown in Fig. 4.1.

A → B	Very rapid compression to half its original volume, and a pressure of 321 kPa.
B → C	Cools at constant volume to return to atmospheric pressure.
C → A	Expands at constant pressure to the original volume.

Fig. 4.1

(a) On Fig. 4.2, sketch a diagram representing the processes in Fig. 4.1 on a graph of the variation with volume of pressure of the gas.

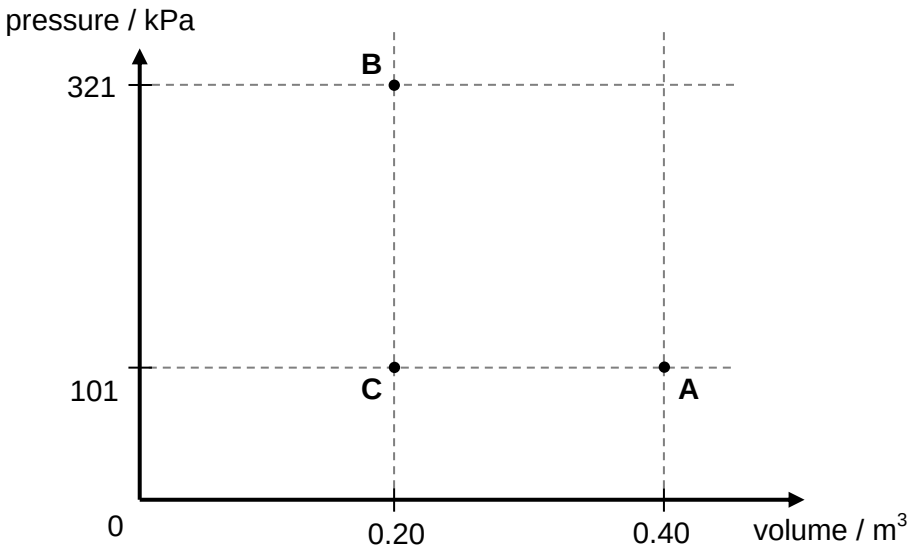


Fig. 4.2 [1]

(b) Given that the gas at **C** is at a temperature of 10 °C, calculate the amount of gas in the container.

amount of gas = …… mol [1]

(c) Determine the net work done on the gas after the three processes.

work done on gas = …… J [3]

(d) The cooling in process **B → C** is measured to be 66 000 J. By using the first law of thermodynamics, determine the heating of the system in **C → A**.

heating of gas = …… J [2]

[Turn over

5 For the purpose of measuring the electrical resistance of shoes through the body of the wearer to a metal ground plate, the National Standards Institute (NSI) uses the circuit shown in Fig. 5.1. The potential difference ΔV across the 1.00 MΩ resistor is measured with an ideal voltmeter.

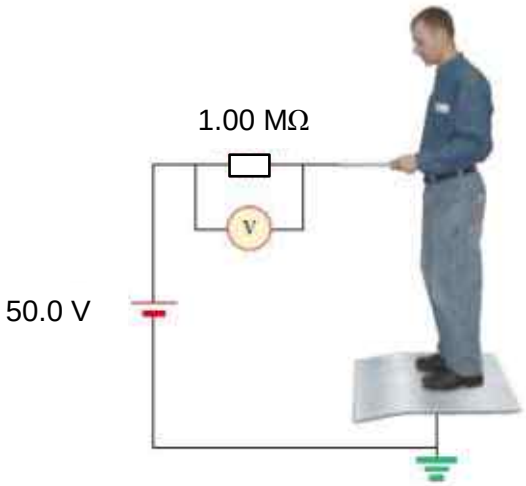


Fig. 5.1

(a) Show that the resistance of the shoes is given by

$$R_{shoes} = 1.00 \times 10^6 \left(\frac{50 - \Delta V}{\Delta V} \right)$$

[1]

(b) In a medical test, a current through the human body should not exceed 150 μA.

Show with calculations, if the current delivered by the circuit exceeds 150 μA. State any assumptions made in your calculations.

.....

..... [2]

(c) State and explain how the measured value of the resistance of the shoes will change if the voltmeter is not ideal.

.....

.....

..... [2]

[Turn over

6 **(a)** **(i)** Define the *tesla*.

.....

.....

..... [1]

(ii) Express the tesla in terms of the product of its base units.

base units = ... [1]

(b) Two long straight current-carrying conductors X and Y are placed parallel to each other. Conductor X carries a current of 2 A while conductor Y carries a current of 1 A. Both directions are into the plane of the paper.

Sketch the magnetic flux pattern due to X and Y in Fig. 6.1 below. [2]



top view

Fig. 6.1

(c) A third conductor Z with a current of 1 A into the plane of the paper is placed on the right of Y.

Y is of equal distance from X and Z.

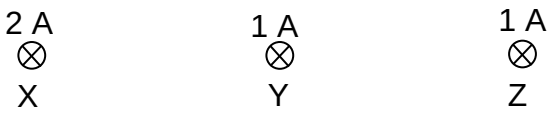


Fig. 6.2

(i) Indicate with clear labelling on Fig. 6.2 the forces acting on Y. [1]

(ii) The direct current in conductor Z is now replaced by a sinusoidal alternating current of peak value 2 A.

Describe the variation of the resultant force with time experienced by Y. You may sketch a graph to illustrate your answer.

.....

.....

..... [2]

[Turn over

Section B (40 marks)

Answer **two** questions from this Section in the spaces provided.

7 **(a)** An electrical signal is sent to a loudspeaker which causes the cone of the loudspeaker to move in a direction parallel to its axis.

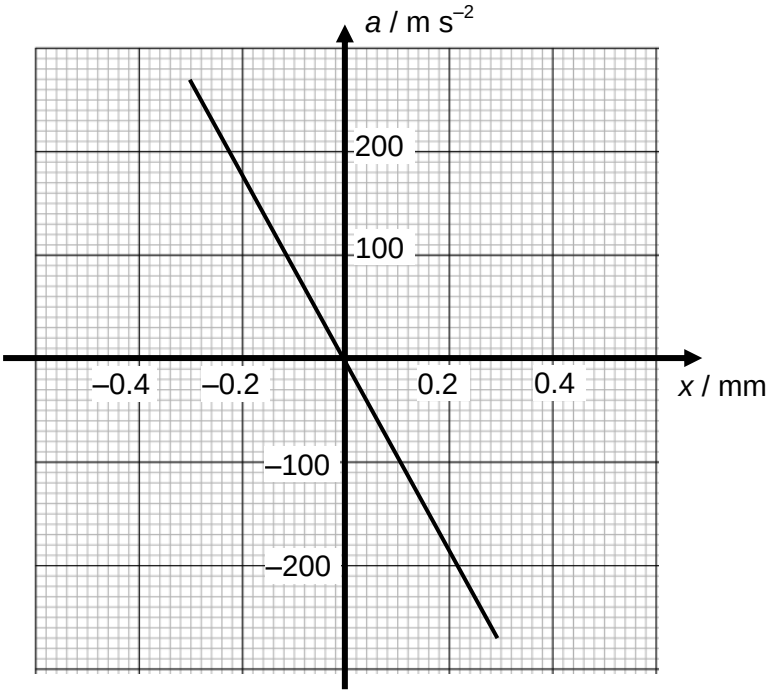


Fig. 7.1

The variation of the acceleration *a* against displacement *x* of the cone is shown in Fig. 7.1.

(i) By making reference to Fig. 7.1, explain how it can be concluded that the cone is undergoing simple harmonic motion.

.....

.....

..... [2]

(ii) Determine the frequency of the electrical signal fed to the loudspeaker.

frequency = ... Hz [2]

(iii) Hence or otherwise, find the maximum speed of the cone.

speed = …….. m s^{-1} [2]

(iv) Explain what will happen to the frequency of the vibrations of the cone if it was replaced with another cone that is heavier but the same electrical signal is applied.

……

……

…… [1]

(b) The loudspeaker mentioned in **(a)** was attached to the end of an open pipe. A signal generator was then connected to it. At a particular frequency, a stationary wave formed inside the pipe.

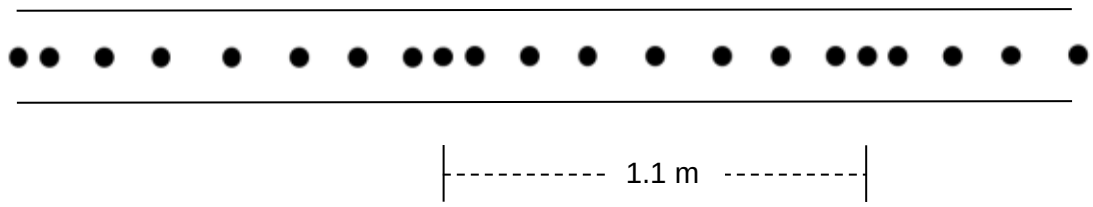


Fig. 7.2

Fig. 7.2 shows the horizontal displacement of the particles along a section of the pipe at an instant in time.

(i) Explain the formation of the stationary wave in the pipe.

……

……

…… [2]

[Turn over

(ii) Determine the node-to-node distance of the sound wave in the pipe.

distance = …… m [1]

(iii) The frequency of the sound wave produced by the loudspeaker is slowly increased from a very low value. A series of loud and soft sounds is heard in the pipe.

In Fig. 7.3, show how the amplitude of the resultant wave varies from one end to the other for the **second** instance a loud sound is heard in the pipe.

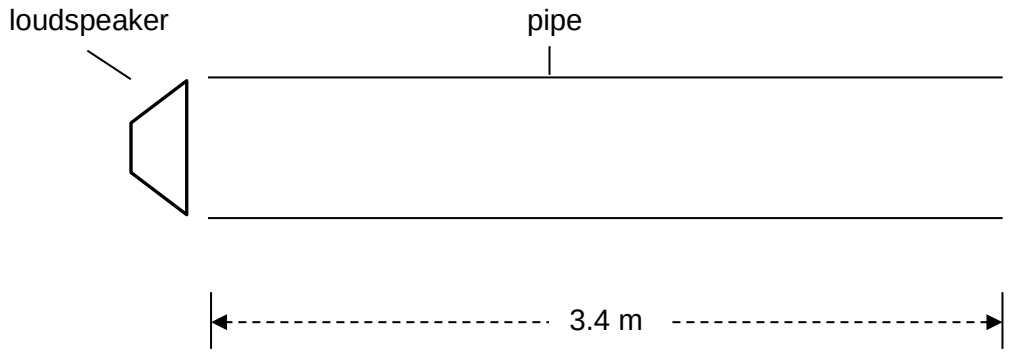


Fig. 7.3

[2]

(iv) State the phenomenon and hence explain why a loud sound is heard in the pipe at that frequency.

……

……

…… [2]

(v) Given that the speed of sound is 340 m s^{-1}**,** calculate the fundamental frequency of the pipe.

frequency = …… Hz [2]

(c) Two of the loudspeakers mentioned in **(a)** and **(b)** are driven by the same oscillator and are located on a vertical pole a distance of 8.0 m away from each other.

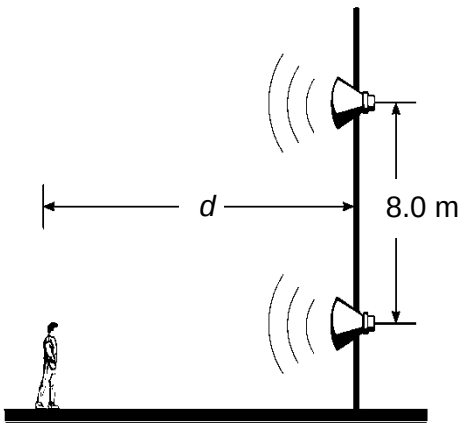


Fig. 7.4

A man walks towards the lower loudspeaker in a direction perpendicular to the pole as shown in the Fig. 7.4 while the loudspeakers are producing sound of wavelength 2.0 m. The lower speaker is at the same height as the ears of the man.

As the man walks towards the lower loudspeaker, he hears a series of maximum and minimum in sound intensities.

(i) Show that the distance d that the man is away from the lower loudspeaker when the intensity of the sound is a minimum, can be expressed as

$$d = \frac{63 - 4n^2 - 4n}{2(2n+1)}, \text{ where } n = 0, 1, 2 \ldots$$

[2]

(ii) Hence or otherwise, find the number of times that the man will hear a minimum in sound intensity when he walks towards the lower loudspeaker from 50 m away.

no. of minimum = ……. [2]

[Turn over

8 **(a)** The three lowest energy levels of the chromium atoms in a ruby laser are shown in Fig. 8.1. The energy of the chromium atom is taken to be zero at E_1.

During optical pumping, electromagnetic radiation of wavelength 550 nm excites chromium atoms from E_1 to E_3. Lasing transition takes place between E_2 and E_1.

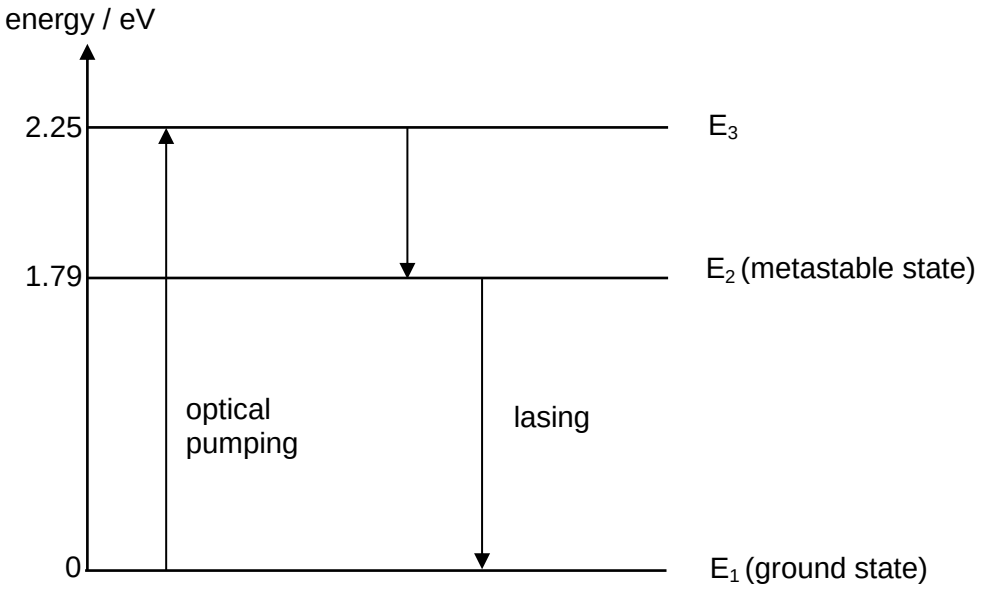


Fig. 8.1

(i) State what is meant by *stimulated emission*.

.....

..... [1]

(ii) Show that the wavelength of the photons that is emitted during stimulated emission is 694 nm.

wavelength = ... nm [1]

(iii) Explain how lasing is achieved between E_2 and E_1.

.....

.....

.....

.....

.....

.....

..... [3]

(iv) Explain why optical pumping using photons of wavelength 694 nm to chromium atoms to achieve lasing is not advisable.

.....

.....

..... [2]

(b) A student uses the ruby laser in **(a)** to irradiate a metal surface with photons in a photoelectric emission experiment. The graph of stopping potential against frequency of incident light falling on the metal surface is shown in Fig. 8.2.

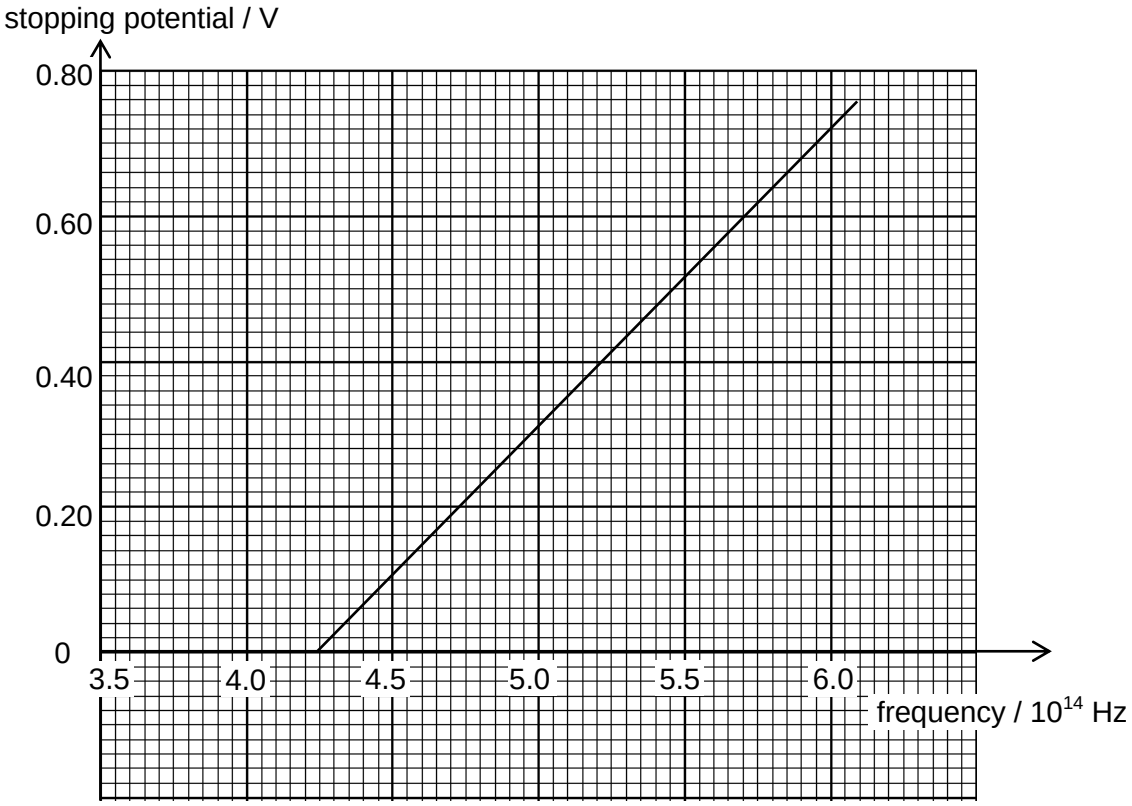


Fig. 8.2

(i) State what is meant by *stopping potential*.

.....

..... [1]

[Turn over

(ii) Using Fig. 8.2, determine

1. the Planck's constant.

Planck's constant = …….. J s [2]

2. the work function for the metal.

work function = …….. eV [1]

(iii) Hence or otherwise, determine the stopping potential when the lasing photons in **(a)** are incident on the metal surface.

stopping potential = …….. V [2]

(iv) Explain why the graph in Fig. 8.2 does not extend below the horizontal axis.

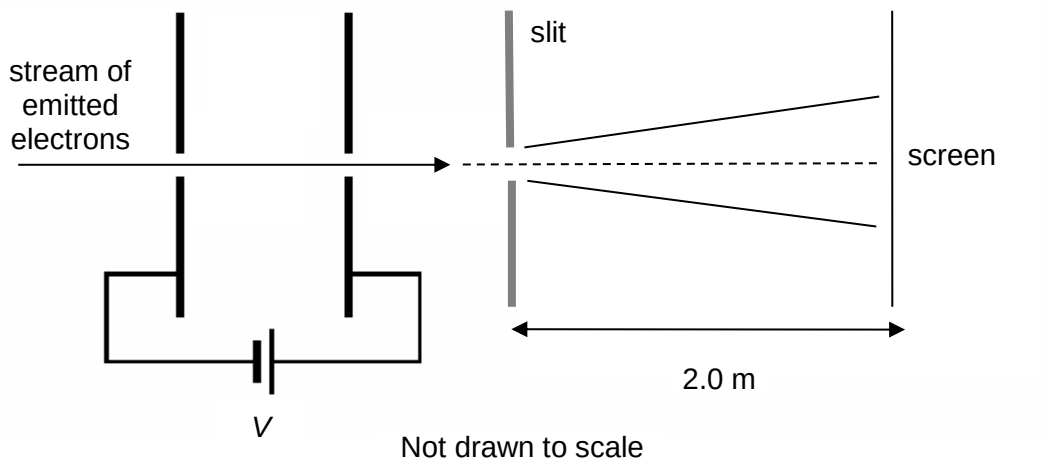
……

……

…… [2]

(c) In order to observe the wave nature of electrons, the student decides to perform an electron diffraction experiment.

An electron diffraction experiment is set up as shown in Fig. 8.3. The width of the slit is 3.8×10^{-10} m and the screen is placed 2.0 m from it.



Not drawn to scale

Fig. 8.3

(i) If the stream of emitted electrons in Fig. 8.3 has electrons of average initial kinetic energy of 6.8 eV each, calculate the accelerating voltage required to produce electrons with wavelength 0.17 nm.

accelerating voltage = …….. V [3]

[Turn over

(ii) For an electron passing through the slit, the uncertainty in its position Δx and the uncertainty in its momentum Δp are related by the following expression and is shown in Fig. 8.4.

$$\Delta x \, \Delta p \approx \frac{h}{2\pi}$$

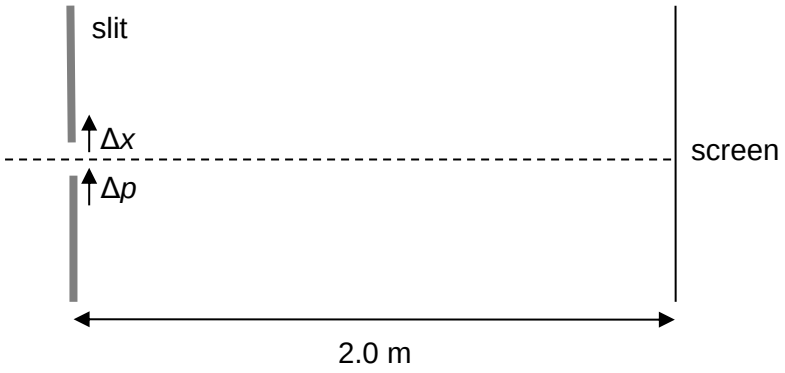


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Fig. 8.4

Calculate the uncertainty in the momentum of an electron after passing through the slit.

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

9 **(a)** Nuclear fusion can be achieved using two deuterium ${}^{2}_{1}\mathrm{D}$ nuclei as reactants and bringing them sufficiently close for the attractive nuclear force to be strong enough for fusion. The reaction has two possible pathways generating either a tritium ${}^{3}_{1}\mathrm{T}$ nuclide and particle X, or a ${}^{3}_{2}\mathrm{He}$ isotope of helium and particle Y, as shown in Fig. 9.1.

Reaction 1: $\quad {}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} \rightarrow {}^{3}_{1}\mathrm{T} + \mathrm{X}$

Reaction 2: $\quad {}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} \rightarrow {}^{3}_{2}\mathrm{He} + \mathrm{Y}$

Fig. 9.1

(i) State what is meant by *nuclear fusion*.

.....

..... [2]

(ii) By sketching a suitable graph and by making reference to binding energy per nucleon, explain why the nuclear fusion of deuterium causes a release of energy.

.....

.....

.....

.....

.....

..... [3]

(iii) State the identity of

1. Particle X: .....

2. Particle Y: ..... [2]

[Turn over

(b) Fig. 9.2 shows the masses of different particles.

nucleus	mass of nucleus / u
deuterium	2.0141
tritium	3.0160
proton	1.0073
neutron	1.0087

Fig. 9.2

(i) Using data in Fig. 9.2, calculate the energy released in reaction 1.

energy released = …….. MeV [3]

(ii) Although energy is released in the nuclear fusion reaction, a large amount of energy is required to initiate the fusion reaction.

Explain why it requires a large amount of energy to start a fusion reaction.

……

……

……

…….. [2]

(c) It is known that tritium (${}^{3}_{1}\mathrm{T}$) is a radioactive isotope of hydrogen. Tritium spontaneously decays into helium-3 (${}^{3}_{2}\mathrm{He}$), with a decay constant of 0.056 year^{-1}.

(i) Explain what is meant by a *spontaneous* decay.

……

…….. [1]

(ii) State the type of radiation emitted when tritium decays into helium-3.

…….. [1]

(iii) On Fig. 9.3, sketch a graph to show how, starting with 7.5×10^{17} nuclides of tritium, the activity of the radioactive decay changes with time. Include the duration of at least three half-lives in your sketch and label all key points clearly.
[4]



Fig. 9.3

(iv) Despite radioactive tritium being produced in a nuclear fusion reaction, suggest an advantage of nuclear fusion over fission for energy generation.

……

……... [1]

(v) A scientist experiments with using different thickness of lead to provide shielding against the type of radiation in **(c)(ii)**.

Explain why, although the lead container provides adequate shielding for the particle emissions, some X-ray radiation may be detected outside the lead container.

……

……... [1]

END OF PAPER

[Turn over

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River Valley High School Preliminary Examination 2 Paper 1 Mark Scheme

Question Number			Question Number	
1	**D**		**21**	**A**
2	**C**		**22**	**C**
3	**D**		**23**	**C**
4	**D**		**24**	**C**
5	**B**		**25**	**B**
6	**A**		**26**	**A**
7	**B**		**27**	**A**
8	**A**		**28**	**C**
9	**A**		**29**	**C**
10	**A**		**30**	**B**
11	**D**		**31**	**C**
12	**B**		**32**	**C**
13	**D**		**33**	**B**
14	**D**		**34**	**B**
15	**D**		**35**	**B**
16	**B**		**36**	**C**
17	**A**		**37**	**D**
18	**D**		**38**	**A**
19	**C**		**39**	**D**
20	**A**		**40**	**D**

1	**Answer: D** Options A, B and C are all possible units for electric field strength and they can be shown to be equivalent.
2	**Answer: C** Vector quantities: velocity, moment, magnetic flux density. Scalar quantities: magnetic flux, electric current, pressure, distance between 2 points, electric potential.
3	**Answer: D**

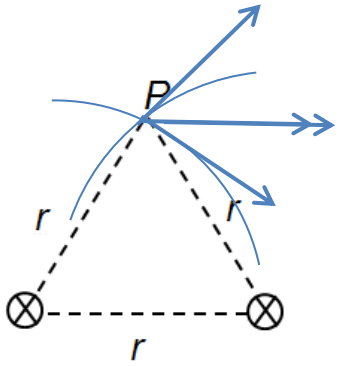
4	**Answer: D** solution: $L = ½ g T^2$ … (1) $½ L = ½ g t^2$ … (2) (2)/(1): $½ = (t/T)^2$ $t = 0.71 T$ wrong option: student assume constant speed $\Rightarrow$ 0.50 T wrong option: student mixes up T and L$\Rightarrow$ 0.25 T 0.5T for 0.25L
5	**Answer: B** $T – 80 g = 80 a$ … (1) $120 g – T = 120 a$ … (2) (1) + (2): $40 g = 200 a$ $a = 1.962$ $s_1 = 18 – s_2$ $v^2 = u^2 + 2as \Rightarrow s = v^2 / 2a$ $v^2 / 2a = 18 – v^2 / 2a$ $v = 5.9$ wrong option: $a = (120 g – 80 g) / 80 = 4.905$ $v = 9.4$ wrong option: loss in Ep of barrel = gain in Ek of system $120 g (9) = ½ (120 + 80) v^2$ $v = 10.3$
6	**Answer: A**
7	**Answer: B**

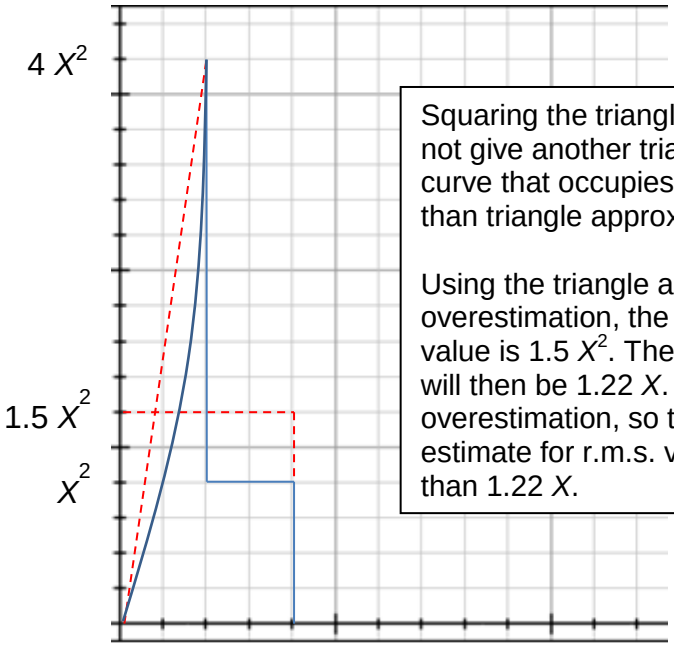
8	**Answer: A** Let the change in depth be *d*, Area of the cube = 0.81 m^2 By the principle of flotation, Weight of the load = weight of the water displaced by the load 400 = 1000 (9.81) (0.81*d*) d = 0.0503 m Wrong option: student uses ρVgd 400 = 1000 (9.81) 0.729 d d = 0.0559 Wrong option: student assumes fully submerged cube.
9	**Answer: A** At the highest point of projectile, there is kinetic energy, hence potential energy is lesser than before (smaller height).
10	**Answer: A** E_K = ½ mv^2 = ½ m (u^2 + 2 a s) Hence E_K varies linearly with distance.
11	**Answer: D** A centripetal force is required in order for an object to move in a circle, which is provided in this case by the frictional force. However, when the turntable is rotating too fast, frictional force is unable to provide the required centripetal force for coin to continue moving in a circle thus it will fly off tangentially.
12	**Answer: B** difference in *v* = $(r_{Radar} - r_{Earth})\omega = 1500\frac{2\pi}{24\times60\times60} = 0.11$ m s^{-1}
13	**Answer: D** Both masses should move in circular motion with the <u>same angular velocity</u>. For m_1, $\frac{Gm_1m_2}{d^2} = m_1r\omega^2$ ---- (1) For m_2, $\frac{Gm_1m_2}{d^2} = m_2(d-r)\omega^2$ ---- (2) Solving (1) and (2), $r = \frac{m_2}{m_1+m_2}d$

14	**Answer: D** Using conservation of energy, loss in gPE = gain in E_k. $\frac{Gm_Am_B}{6} - \frac{Gm_Am_B}{60} = \frac{1}{2}m_A{v_A}^2 + \frac{1}{2}m_B{v_B}^2$ $\frac{G(20)(40)}{6} - \frac{G(20)(40)}{60} = \frac{1}{2}(20){v_A}^2 + \frac{1}{2}(40){v_B}^2$ ---- (1) $m_Av_A = m_Bv_B$ $(20)v_A = (40)v_B$ ---- (2) Solving (1) and (2), $v_B = 1.2 \times 10^{-5}$ m s^{-1}
15	**Answer: D** Example: Ideal gas U = 3/2 NkT, if same U, can be different T and different N.
16	**Answer: B** $m_bc_b\Delta T_b = m_wc_w\Delta T_w + m_{wv}l_v$ $(300)(0.10c_w)(5m_w) - (70)(c_w)(m_w) = m_{wv}l_v$ $80c_wm_w = m_{wv}l_v$ $\frac{80}{540} = \frac{m_{wv}}{m_w} = 0.15$
17	**Answer: A** By comparison, $\omega^2 = \frac{k}{m}$ Therefore, $\frac{2\pi}{T} = \sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$
18	**Answer: D** $E_K = \frac{1}{2}m\omega^2({x_0}^2 - x^2)$ $E_P = \frac{1}{2}m\omega^2x^2$ When $E_K = E_P$, $({x_0}^2 - x^2) = x^2$ Therefore, $x = \frac{x_0}{\sqrt{2}} = 0.707x_0$

19	**Answer: C** Average intensity of radiation at Mars $= \left(\frac{(\text{distance of Earth from Sun})}{(\text{distance of Mars from Sun})} \right)^2 \times \text{Intensity of radiation at Earth}$ $= \left(\frac{150}{230} \right)^2 \times 1300$ $= 552.93\ \text{W m}^{-2}$ Radiation incident on Mars = Projected surface area of Mars x average solar intensity of Mars. $= 552.93 \times \pi(3400000)^2 = 2.0 \times 10^{16}\ \text{W}$
20	**Answer: A** Particles on the left of A are moving right while particles on the right of A are moving left, thus A shows a region of compression.
21	**Answer: A** The resultant amplitude when two waves with planes of polarization perpendicular to each other meet in phase and out of phase are both $\sqrt{2}x_0$, thus the difference is zero.
22	**Answer: C** At the intersection of the path of the microphone and the line joining the 2 loudspeakers, the path difference from the loudspeakers to microphone is 3 times that of the wavelength. Thus those 2 points are the 3rd order maxima of the interference. Therefore, there must be 12 maxima in total.
23	**Answer: C** Using $F = -\frac{dU}{dr}$, Force = – gradient of U-r graph = $-\frac{8.4 \times 10^{-11} - 0}{0.012 - 0}$ = -7.0×10^{-9} N
24	**Answer: C** Effective electric field strength points in the direction of A. Hence, the electric force acting on a negative charge points in the opposite direction of electric field strength.
25	**Answer: B**

26	**Answer: A** Resistance of a conductor $R = \rho \frac{l}{A}$ $\frac{R_A}{R_B} = \frac{l_A}{l_b} \times \frac{A_B}{A_A} = \frac{1}{2} \times \frac{4}{1} = 2$ Thus since potential difference across A and B will be the same when connected in parallel, only ½ the amount of current flowing through B will flow through A.
27	**Answer: A** The four resistors that are not labelled are connected in parallel, thus their effective resistance is one quarter that of resistor X, which can be considered to be in series with resistor X. Since power is proportional to resistance for the same current, the power dissipated by the four resistors is going to be ¼ that of X. Thus power is 2.5 W.
28	**Answer: C** There is current flow in the branch circuit as it is a closed circuit. Looking at secondary branch, p.d. across the e.mf. and *r* resistor (or across the 4.0 Ω resistor alone): $\frac{5.0}{r + 5.0} \times 2.0 = V_s$ At balance point, p.d. across PJ = V_s Applying potential divider to primary driver circuit: $\frac{(\frac{20}{100} \times 10)}{10 + 10} \times 9.0 = V_s$ $\frac{(\frac{20}{100} \times 10)}{10 + 10} \times 9.0 = \frac{5.0}{r + 5.0} \times 2.0$ $r = 6.11 = 6.1 \Omega$
29	**Answer: C** Bqv = m ω v Bq = m ω Bq = m (2π/T) Hence T = constant (since B , m and q 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.

30	**Answer: B**  $2\left(\frac{\mu_0 I}{2\pi r}\cos 30\right) = \frac{\sqrt{3}\mu_0 I}{2\pi r}$
31	**Answer: C** At original distance, maximum movement is 10 units. At closer distance, flux linkage with left solenoid is increased, so when switch is opened, the change in flux linkage is larger than before, so maximum movement will be more than 10 units. Initial deflection to right indicates induced current to oppose increasing flux linkage. As switch is opened, the deflection will show current to oppose decreasing flux linkage, which is to left.
32	**Answer: C** e.m.f. across PO = $\frac{1}{2}B\omega(\sqrt{2}r)^2 = B\omega r^2$ e.m.f. across QO = $\frac{1}{2}B\omega r^2$ (also p.d. across PQ) e.m.f. across RO = $\frac{1}{2}B\omega(\frac{\sqrt{2}}{2}r)^2 = \frac{1}{4}B\omega r^2$ (so p.d. across PR is 3/4) so e.m.f. across QR = $\frac{1}{4}B\omega r^2$ (smallest; correct answer) (for formula, reference: `http://tinyurl.com/gqs3ogq`)
33	**Answer: B** period = $4\times 2.0\times 10^{-3} = 8.0\times 10^{-3}$ $\omega = \frac{2\pi}{8.0\times 10^{-3}} = 785\ \text{rad s}^{-1}$ voltage amplitude = $2\times 1.0 = 2.0\ \text{V}$ current amplitude = 2.0/10 = 0.20 A

34	**Answer: B**  Squaring the triangle graph does not give another triangle, but a curve that occupies smaller area than triangle approximation. Using the triangle as an overestimation, the mean square value is 1.5 X^2. The r.m.s. value will then be 1.22 X. This is an overestimation, so the best estimate for r.m.s. value is less than 1.22 X.
35	**Answer: B** Energy of incident photon = $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{380 \times 10^{-9}} = 5.23 \times 10^{-19}\ J$ Energy of first emitted photon = $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{650 \times 10^{-9}} = 3.06 \times 10^{-19}\ J$ Energy of second emitted photon = $5.23 \times 10^{-19} - 3.06 \times 10^{-19} = 2.17 \times 10^{-19}\ J$ Wavelength of second emitted photon = $\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{2.17 \times 10^{-19}} = 9.15 \times 10^{-7}\ m$
36	**Answer: C** $\frac{T_1}{T_2} = \frac{e^{-2kd_1}}{e^{-2kd_2}} = \frac{1}{5}$ $k = \sqrt{\frac{8\pi^2(9.11 \times 10^{-31})(5.4 - 3.0)(1.6 \times 10^{-19})}{h^2}} = 7.928 \times 10^{9}$ Hence, $d_2 = d_1 - \frac{\ln 5}{2k} = 0.40 \times 10^{-9} - \frac{\ln 5}{2(7.928 \times 10^{9})} = 0.30\ nm$

37	**Answer: D** High transfer of energy happens when high number of protons is incident on eyes per unit time. <u>Wrong options</u> A: Frequency of visible light is considered relatively low compared to ultraviolet and X-ray radiation. B: Energy of photons of visible light is considered relatively low compared to ultraviolet and X-ray radiation. C: Does not address why it is harmful.
38	**Answer: A** <u>Wrong options</u> B: Region D will decrease but region C will increase. C: During forward-biased, electrons will flow from region A to region D. D: Should be Group V atoms in region B, not Group III.
39	**Answer: D** 134: correct neutron number
40	**Answer: D** 118: correct value, after adding in background count rate $C_X = C_Y = 508 - 28 = 480$ $C_X(1\,\text{year}, 3\,\text{half - lives}) = (\frac{1}{2})^3(480) = 60$ $C_Y(1\,\text{year}, 4\,\text{half - lives}) = (\frac{1}{2})^4(480) = 30$ $C_{mixture}(1\,\text{year}, \text{plus background}) = 60 + 30 + 28 = 118$

2016 PRELIM 2 PAPER 2 MARK SCHEME

1 **(a)**

$$X = \frac{V}{I} = \frac{5.00}{2.7\times10^{-3}} = 1851.9V$$ [M1]

$$\frac{\Delta X}{X} = \frac{\Delta V}{V} + \frac{\Delta I}{I}$$

$$\frac{\Delta X}{1851.9} = \frac{0.03}{5.00} + \frac{0.2}{2.7}$$ [M1]

$$\Delta X = 148.3 \approx 100$$

$$X + \Delta X = 1900 \pm 100\Omega$$ [A0]

(b)

- Anomalous data can be identified.
- Systematic errors can be identified and eliminated from measured values
- Random errors can be identified and their effects reduced.

[B2]

Any 2 of the 3 points.

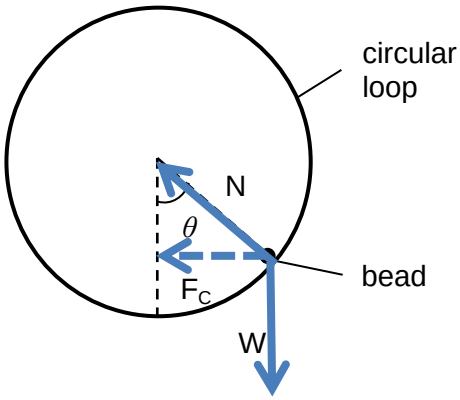
2 **(a)** force on body A is equal in magnitude to force on body B (from A) [M1]
forces are in opposite directions [A1]
forces are of the same kind

(b) $F_A = -F_B$ and $t_A = t_B$ [M1]
$\Delta p = F_A t_A = -F_B t_B$ [M1]

(c) **(i)** graph: momentum change occurs at same times for both spheres [B1]
final momentum of sphere B is to the right [M1]
and of magnitude 5 N s [A1]

(ii) change in momentum / time = 9 / 0.0075 [C1]
= 1200 N [A1]
to the left [A1]

3 **(a)** [B1]



No marks if forces not labelled or forces missing.

(b) Considering forces on the bead,

$N\cos\theta = mg$

$N\sin\theta = F_c = \dfrac{mv^2}{r}$

$\tan\theta = \dfrac{r\omega^2}{g}$

$\dfrac{\sin\theta}{\cos\theta} = \dfrac{0.2\sin\theta\left(\dfrac{2\pi}{0.75}\right)^2}{9.81}$ [M1]

$\theta = 45.7°$ [A1]

(c) θ will decrease, if circle is rotating at a slower rate, centripetal force will decrease thus the horizontal component of the reaction force will be smaller and θ will be smaller. [M1] [A1]

4 **(a)** Consider forces in horizontal direction,
$F_E = T\sin\theta$ --- (1)

Consider forces in vertical direction, [C1]
$mg = T\cos\theta$ --- (2)

Combining (1) and (2),
$\tan\theta = \dfrac{F_E}{mg} = \dfrac{q^2}{4\pi\varepsilon_0 d^2 mg}$ --- (3)

Considering geometry,
$\dfrac{d}{2} = l\sin\theta$ --- (4) [C1]

Combining (3) and (4) and $\sin\theta = \tan\theta$, [A1]
$\dfrac{q^2}{4\pi\varepsilon_0 d^2 mg} = \dfrac{d}{2l}$

$d = \left(\dfrac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$ (shown)

(b) Using $d = \left(\dfrac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$,

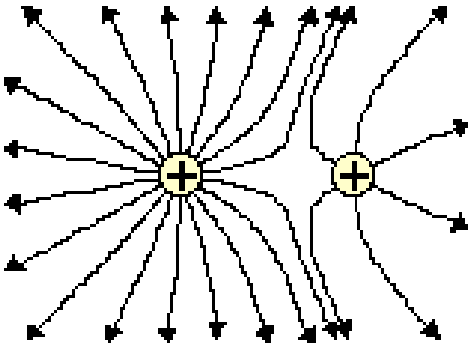
$d = \left(\dfrac{(12\times10^{-9})^2(0.18)}{2\pi\varepsilon_0(0.020)g}\right)^{\frac{1}{3}} = 0.0133$ m [A1]

(c) (i)

Using $d = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg} \right)^{\frac{1}{3}}$, d will not change as the product of q and $\frac{1}{2}q$ will not lead to a change in the equation while m and l are also kept constant. [B1]

Using $tan\theta = \frac{q^2}{4\pi\varepsilon_0 d^2 mg}$, the changes in the charges will not affect θ_1 and θ_2 since d and m are kept constant. [B1]

(c) (ii)



Source: http://www.physicsclassroom.com/class/estatics/Lesson-4/Electric-Field-Lines

Correct E-field lines spacing (closer field lines nearer to charge A)

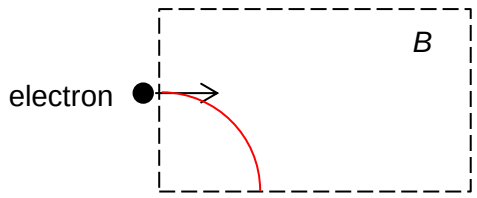
[B1]

Correct direction of E-field lines with neutral point nearer to charge B

[B1]

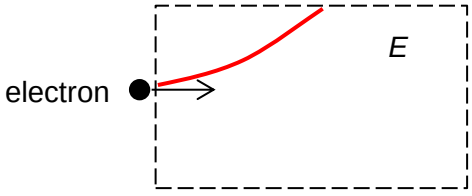
Important: The diagram is should be drawn without any intersection of field lines and the field lines should be perpendicular to the surface of the charge. The top and bottom half of the diagram should also be proportional.

5 (a) (i)



Circular Path downwards [A1

(ii)



Parabolic path upwards [A1

(b) Magnetic force provides for centripetal force

$Bqv = m v^2 / r$
$B = m v / qr = (9.11\times10^{-31})(1.8\times10^{8}) / (1.6\times10^{-19})(0.012) = 8.5 \times 10^{-2}$ T [M1]

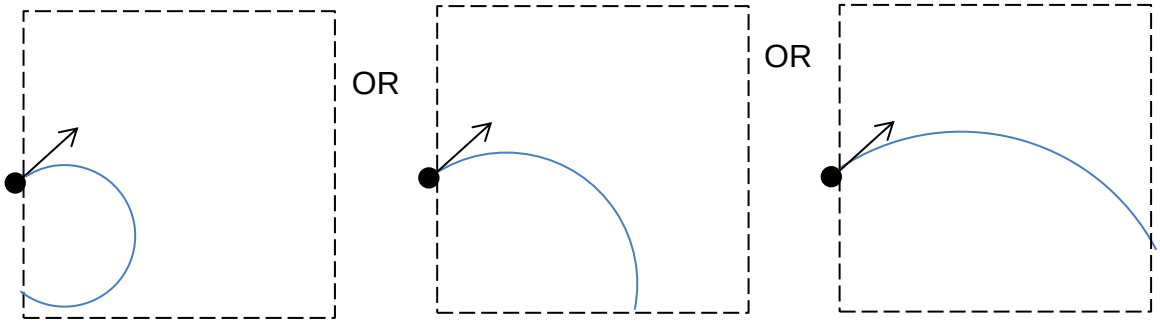
When undeviated
Magnetic force = electric force
$Bqv = qE$
$v = E / B$
$E = v B = (1.8 \times 10^{8})(8.5 \times 10^{-2})$ [M1]
$= 1.5 \times 10^{7}$ [A1]

(c) **(i)** Undeviated [A1]

(ii) Undeviated [A1]

(iii) Curve path upwards [A1]
(circular path not accepted)

(d)



[A1]

6 (a) In a p-n junction, electron-hole recombination forms an internal electric field which opposes further diffusion of both electrons and holes across a region known as the depletion region. [B1]

When a potential difference is applied across such that p-type is at a higher potential than n-type (or in forward bias/p-type connected to positive terminal), the width of the depletion region is decreased so holes and electrons are allowed to flow through allowing conduction to occur. [B1]

When the potential difference is applied such that n-type is at a higher potential than the p-type, (or in reversed bias/n-type connected to positive terminal), the depletion region is increased which prevents the flow of charge carriers across the region, and the p-n junction behaves as a very high resistance. [B1]

This allows the p-n junction to act as a rectifier as current is allowed to flow in one direction and not the other.

(b) When temperature increases for intrinsic semiconductor, electrons are excited from valence band to conduction band and holes are formed in valence band. The increases in charge carriers are electrons in conduction band and holes in valence band and these help to lower the resistance in the material. [B1]

The conduction band of metal is partially filled with electrons. With thermal excitation, there is negligible effect on number density of the electrons. Instead, [B1] there is increase in lattice vibrations in the material which results in higher [B1] resistance in metal.

7 (a) (i) $\mu = \frac{B}{H}$. The ratio of *B/H* decreases with increasing values of *B*, taking points from curve A. So the magnetic permeability of iron decreases. [A1] [A1]

(ii) $\Delta\Phi = NA(B_2 - B_1) = (40000)(0.090)(-100 \times 10^{-3})$ [C1]

$= -360$ Wb [A1] [2]

(iii) $\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{-360}{0.25 \times 1/50}$ [C1]

$= 7.2 \times 10^4$ V (2sf) [A1] [2]

(b) (i) [2]

B_{max} / T	P_h / kW	lg (B_{max} / T)	lg (P_h / W)
0.250	3.30	-0.602	3.519

Fig. 7.4

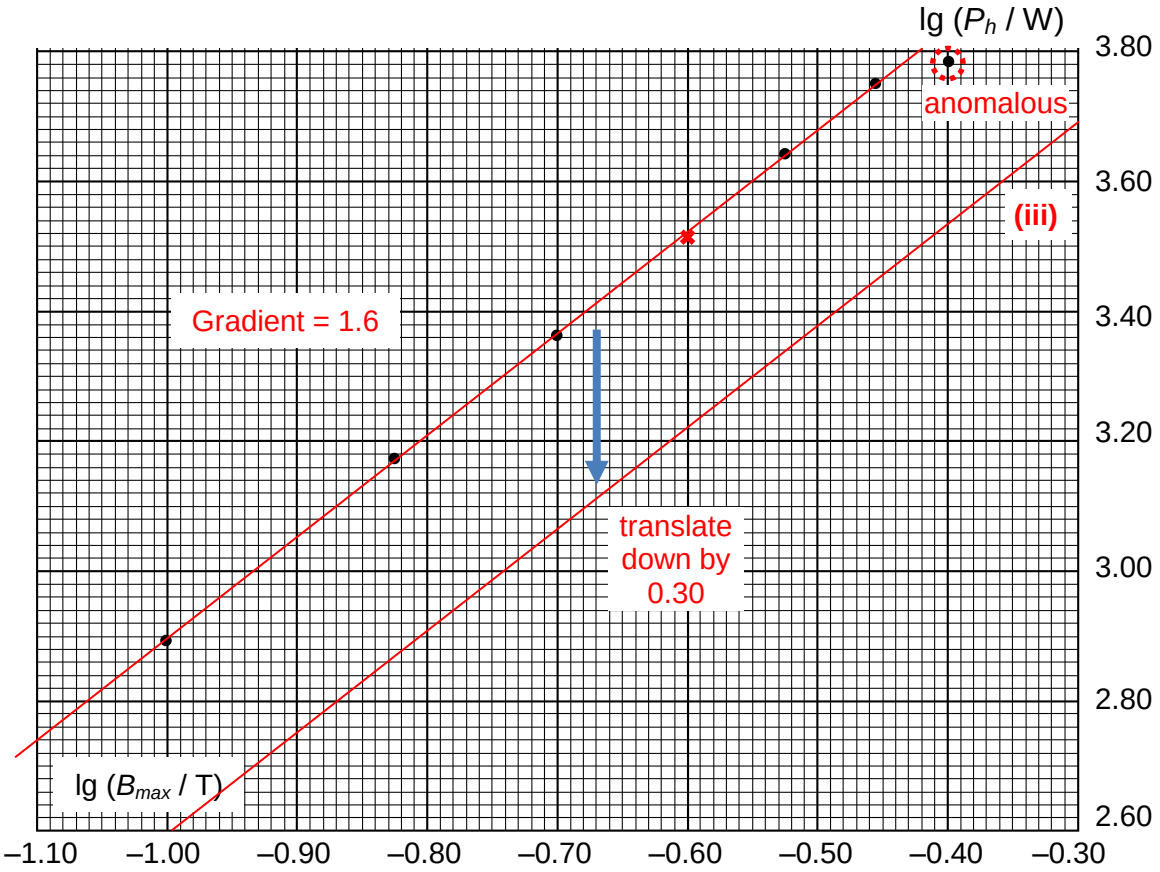


Fig. 7.5

Correct computation of data in table [A1]
Correctly plotted point [A1]

(ii) $\lg P_h = \lg K_h f + n \lg B_{max}$ [4]

gradient $= n$

y – intercept $= \lg K_h f$

Correctly drawn best fit line [A1]

$$gradient = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= 1.5995 = 1.6$$

$n = 1.6$ [A1]

$y = \lg K_h f + (1.5995)x$ [C1]

$\lg K_h f = 4.4794$

$$K_h = \frac{10^{4.4794}}{50} = 603 \text{ J T}^{-1.6}$$ [A1]

(iii)
- Same gradient straight line [B1]
- Shifted down by 0.30 * [B1]

[2]

$* \lg P_h = \lg K_h f + n \lg B_{max}$

y - intercept is $\lg K_h f$, or $(\lg K_h + \lg f)$ so if f is halved,

then intercept will become $(\lg K_h + \lg \frac{1}{2} f)$

$= (\lg K_h + \lg f + \lg \frac{1}{2}) = (\lg K_h + \lg f - 0.301)$

(c) (i) Read off from graph, at B_{max} = 0.20, P_{loss} = 2.30 kW [2]

Average power supplied to primary coil = (4500)(10)(0.5) = 22500 W [C1]

$$efficiency = \frac{22500 - 2300}{22500}$$
$$= 89.7\%$$ [A1]

(ii) Average power supplied to secondary coil = 22500 – 2300 =20200 W [2]

$$V_{rms\,(secondary)} = \frac{40000}{200}(\frac{4500}{\sqrt{2}})$$
$$= 636396 \text{ V}$$ [C1]

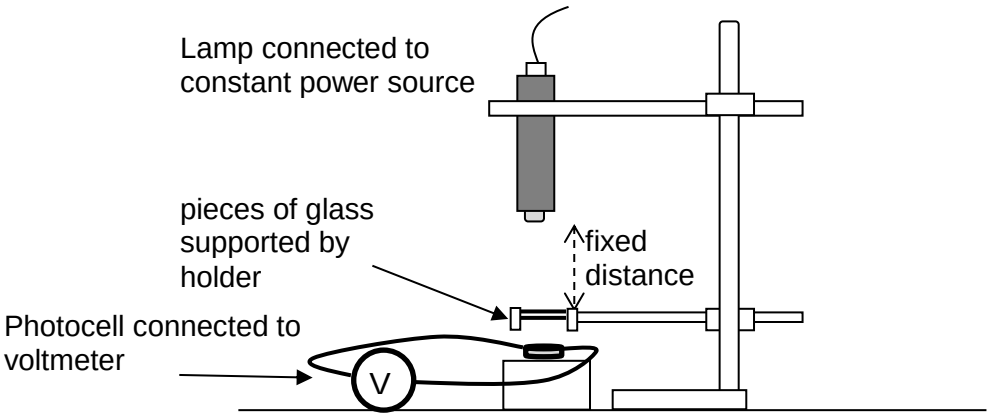
$$P_{loss} = I^2 R = (\frac{P}{V})^2 R$$
$$= (\frac{20200}{636396})^2 (20)$$
$$= 0.020 \text{ W}$$ [A1]

(iii) It is an <u>overestimate</u> as it does not factor in other losses, such as copper loss in the resistance of the wires, or eddy currents in the iron core. [1]

Q8

Planning Marksheme (12 marks)

Diagram: [2 mk]



[Labelled diagram of apparatus: lamp, glass sheet and photocell in line.
Voltmeter connected in parallel to photocell]

(a) the identification and control of variables, [2 mk]

n is the independent variable and E is the dependent variable
control includes distance from light to photocell kept constant, intensity of light kept constant, constant voltage across lamp/current through lamp/brightness (any 1 control) Do not allow 'same lamp/output'.

(b) the equipment you would use, [1 mk]

Use micrometer screw gauge to measure thickness of glass sheet
Voltmeter to measure emf

(c) the procedure to be followed, [3 mk]

- Take at least 2 readings of thickness of glass and find average
- Direct light at glass, read emf E of photocell
- Record n and E, repeat with additional piece of glass

<u>Additional detail [any other point]</u>

- Preliminary readings: adjust distance of lamp, glass and detector until noticeable reading is obtained on voltmeter. Try a few pieces of glass to get the suitable range of thickness such that there is significant reading on the voltmeter.
- Use small distance/high intensity to gain large reading.
- Method to check output of lamp is constant e.g. measure current through/p.d. across
- lamp/regularly check V0 with no glass.
- Clean sheets of glass before use.
- Direction of light is perpendicular to glass sheets/constant orientation.

- Do not allow vague computer methods.

(d) how the absorption coefficient is determined from your readings, [2 mk]

$\ln E = -\alpha n t + \ln E_0$

Plot a graph of ln E against n. (Allow ln E against nt)

From graph, calculate gradient

α = (–)gradient / t. (ln *E* against nt then α = (–)gradient)

(e) any precautions that would be taken to improve the accuracy and safety of the experiment. [2 mk]

Perform experiment in a dark room or shield apparatus from ambient light

Reasoned method to prevent burns from hot source, e.g. use gloves

Reasoned method to prevent eye damage from bright/intense source, e.g. shield lamp/ dark glasses/do not look at source directly

Reasoned method to prevent cuts from glass e.g. use gloves.

2016 PRELIM 2 PAPER 3 MARK SCHEME

Section A

1 (a) Weight of Mr Ng = normal reaction force $N = 65 \times 9.81 = 637.65$ N

Taking the ankle as pivot,
sum of clockwise moments = sum of anticlockwise moments
$N \times 15.0 = T \cos 30° \times 6.0$ [C1]
$T = 1840.7 \approx 1800$ N [A1]

(b) Σ of horizontal forces = 0 [C1]
$T \sin 30° = P \sin \theta$
$0.5\ T = P \sin \theta$
$920.37 = P \sin \theta$ …… (1)

Σ of vertical forces = 0 [C1]
$N + T \cos 30° = P \cos \theta$
$637.65 + 1840.7 \cos 30° = P \cos \theta$
$637.65 + 1594.125 = P \cos \theta$
$2231.775 = P \cos \theta$ …… (2)

Dividing (1) by (2):
$\tan \theta = 0.41239$
$\theta = 22°$ [A1]

2 (a) (i) $v^2 = u^2 + 2as$
$(18000/3600)^2 = (24000/3600)^2 + 2a(10.5)$
$a = -0.926$
$f = ma = (1500)(0.926) = 1388 = 1400$ N (shown) [M1]

(ii) $P = fv$
At constant speed, driving force (from engine) = friction
$= (1400)(12)$ [M1]
$= 16800$ [A1]

(b) At maximum speed, driving force = component of weight + friction [M1]
In terms of power, $P_{engine} = P_{friction} + WD_{\text{ against gravity}} / t$

$16800 = 800\ v + mg\ h / t$
$= 800\ v + mg\ d \sin 1° / t$ [M1]
$= 800\ v + mg\ v \sin 1$

$v = \ldots = 15.9 = 16\ m\ s^{-1}$ [A1]

3 **(a)** Satellites that <u>appear to be fixed over one spot above the equator</u> are known as geostationary satellites [B1]

(b) $\omega = \frac{2\pi}{T} = \frac{2\pi}{24 \times 3600} = 7.27 \times 10^{-5}\ rad\ s^{-1}$ [B1]

(c) Gravitational force provides for centripetal force.

$F_g = \frac{Gm_E m_S}{r^2} = m_S r\omega^2$ [B1]

At earth's surface,

$g = \frac{Gm_E}{r^2} = \frac{Gm_E}{(6.4 \times 10^6)^2} = 9.81$ [M1]

$r^3 = \frac{Gm_E}{\omega^2} = \frac{9.81(6.4 \times 10^6)^2}{(7.27 \times 10^{-5})^2}$ [A1]

$r = 42 \times 10^3\ km$

(d) The astronaut is free falling with equal acceleration as the satellite as they are orbiting about the earth. [B1]

Since there is no contact force between the astronaut and the satellite, the astronaut seems to be weightless. [B1]

(e) Using $= -\frac{Gm_E m_S}{r}$, as the radius increases, the potential energy of the satellite increases. [B1]

Using $\frac{Gm_E m_S}{r^2} = \frac{m_S v^2}{r}$, $E_k = \frac{Gm_E m_S}{2r}$. As the radius increases, the kinetic energy of the satellite decreases. [B1]

(f) Launch the satellite near equator and direct the satellite towards East. [B1]

4 **(a)**

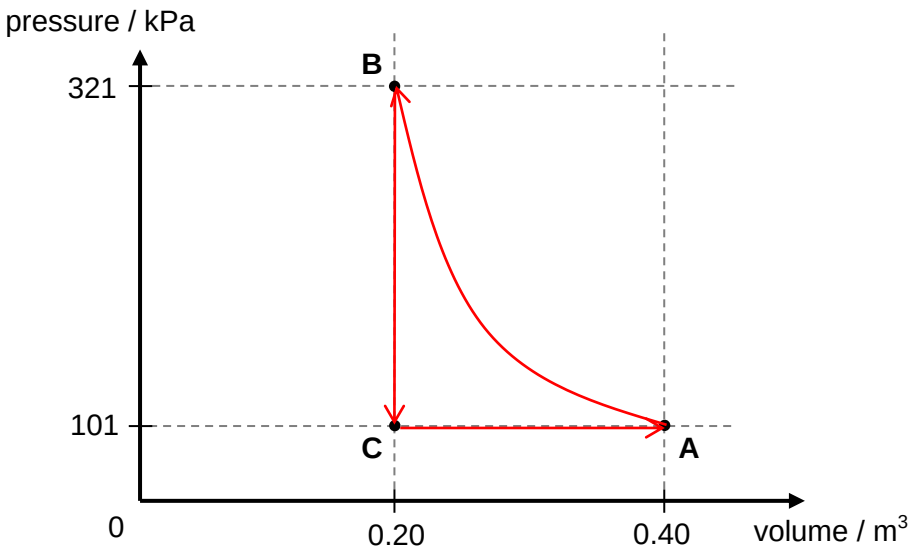


Fig. 4.2

- Correct shape (AB curve, BC and CA straight line) and correct arrow direction. [B1]

(b)

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(101000)(0.20)}{(8.31)(10+273.15)} = 8.5849 = 8.6\,\text{mol} \quad \text{[A1]}$$

(c)

$$\text{Change in internal energy in AB} = \frac{3}{2}(321000 \times 0.20) - \frac{3}{2}(101000 \times 0.40)$$

$$= +35700\ \text{J} = \text{Work done on gas} \quad \text{[C1]} \qquad \text{[C1]}$$

$$\text{Work done during CA} = -p\Delta V = -(101000)(0.40-0.20) = -20200 \quad \text{[C1]} \qquad \text{[C1]}$$

$$\text{No work done on gas during BC}$$

$$\text{Net work done on gas} = 90900 - 20200 = 15500\ \text{J} \quad \text{[A1]} \qquad \text{[A1]}$$

(d) Process A → A is cyclic, so internal energy remains the same. By first law of thermodynamics, $\Delta U = Q + W$, net work done on the gas will be equal to net heat loss by the gas. [C1] [C1]
Since Q = –66000 in B → C, it means that there is heating of the system in process C → A

$$\Delta U = Q + W$$

$$0 = Q - 66000 + 15500$$

$$\text{Heating of system in CA} = 50500\ \text{J} \quad \text{[A1]} \qquad \text{[A1]}$$

5 (a)

$$\Delta V = \left(\frac{R_{1.00M\Omega}}{R_{1.00M\Omega} + R_{shoes}}\right) \times E$$

$$\Delta V = \left(\frac{1.00 \times 10^6}{1.00 \times 10^6 + R_{shoes}}\right) \times 50 \quad \text{[B1]}$$

$$R_{shoes} = 1.00x10^6\left(\frac{50 - \Delta V}{\Delta V}\right)$$

(b) Assume that the resistance of the human body is zero. [B1]

Current through circuit = $\frac{E}{R} = \frac{50}{1.0 \times 10^6} = 50 \times 10^{-6}$ A thus current does not exceed 150 μA. [B1]

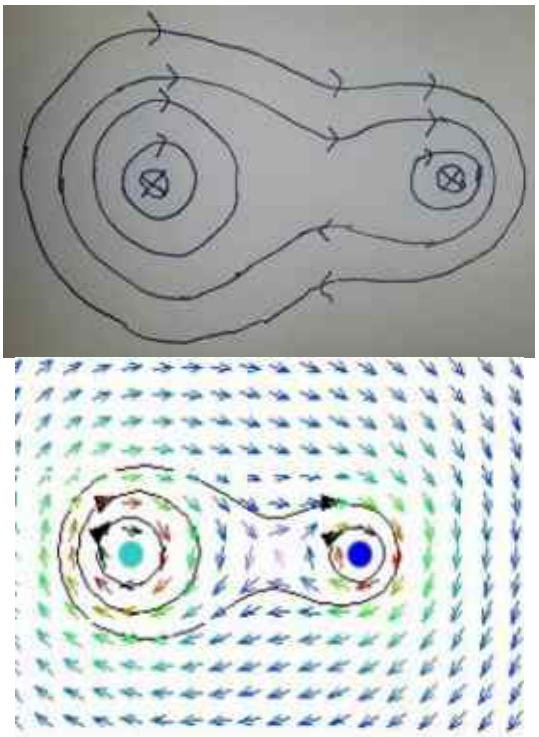
(c) If the voltmeter is not ideal, its resistance is finite and not as high, the effective resistance between the 1.00 MΩ resistor will be lower, and the potential difference across the 1.00 MΩ resistor will be lower [B1] thus the measured value of resistance will be higher according to the expression in (i). [B1] [B1] [B1]

[Turn over

6 **(a)** **(i)** If a long straight conductor carrying a current of 1 amp is placed at right angles to a uniform magnetic field of flux density of 1 tesla, then the force per unit length on the conductor is 1 newton per metre. [A1]

(ii) 1 T = 1 N / Am = kg m s^{-2} / A m = kg s^{-2} A^{-1} [A1]

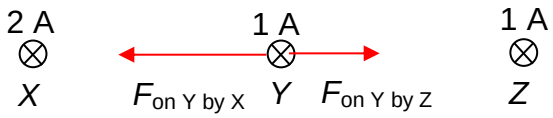
(b) **(i)**



[A2]

[Asymmetry field lines,
More field lines at X,
Arrows correct directions]

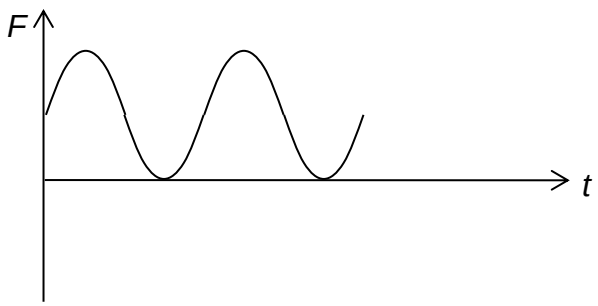
(c) **(i)**



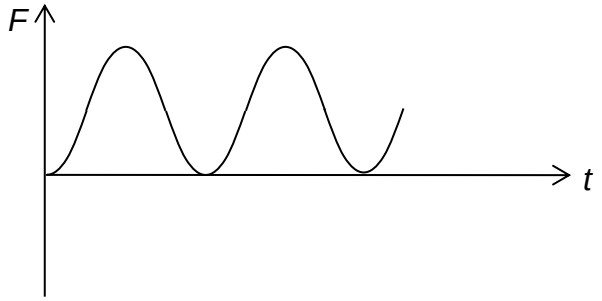
[A1]

[left arrow double in length compared to right arrow]

(ii) **Sinusoidal** variation of resultant force from **0 to maximum** value. [A2]



OR



Section B

7 (a) (i) For SHM, the acceleration is directly proportional to its displacement, [B1]
$\underline{a = -\omega^2 x}$

The graph shows a straight line that passes through the origin, with a negative gradient, which shows that the acceleration of the cone is directly proportional to its displacement, and is opposite that of the displacement. [B1]

(ii) Gradient of graph $= \dfrac{270-(-270)}{-0.3\times10^{-3}-0.3\times10^{-3}} = -900000$ [M1]

$\omega^2 = 900000$

$f = 151 Hz$ [A1]

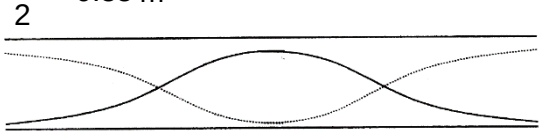
(iii) $v = \omega x_0 = (2\pi f)(0.3\times10^{-3}) = 0.285 \text{ m s}^{-1}$. [C1] [A1]

(iv) It will still be the same, the frequency of the oscillating object will be the same as that of the driving frequency, [B1]

(b) (i) As the incident wave travels down the pipe, it will be reflected at the open end of the pipe (due to pressure differences/difference in density of medium). [B1]

As both incident and reflected waves have the similar amplitude, frequency, speed and move in opposite directions, the incident and reflected wave will superpose to form a stationary wave. [B1]

(ii) $\dfrac{1.1}{2} = 0.55 \text{ m}$ [A1]

(iii)  [A1]

(iv) Resonance. [B1]

At that frequency, resonance occurred and there is maximum transfer of energy from driver to driven system thus a loud sound is heard. [B1]

(v) $f = \dfrac{v}{\lambda} = \dfrac{340}{3.4} = 100 Hz$ [A1]

fundamental f = 100 / 2 = 50 Hz. [A1]

[Turn over

(c) **(i)** $\sqrt{8^2 + d^2} - d = (n + \frac{1}{2})\lambda$ [M1]

$(8^2 + d^2) = (2n + 1 + d)^2$

$(8^2 + d^2) = 4n^2 + 4n + 4nd + 1 + 2d + d^2$ [M1]

$d = \frac{63 - 4n^2 - 4n}{2(2n + 1)}$ [A0]

(ii) Since n > 0, and d > 0, $63 - 4n^2 - 4n > 0$

n = 3.5 or -4.5.

No of times = 4. (explain)

n	0	1	2	3	4
d	31.5	9.166667	3.9	1.071429	-0.94444

8 **(a)** **(i)** Stimulated emission is the process where an incident photon of appropriate energy triggers the emission of photons from excited atoms. [B1]

(ii) $\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{1.79 \times 1.6 \times 10^{-19}} = 6.94 \times 10^{-7}\ m = 694\ nm$ [B1]

(iii) When large numbers of atoms de-excite from E_3 to E_2 and remain at E_2 due to metastable state as compared to E_1, population inversion is achieved. [B1]

When one spontaneous emission of photon from E_2 to E_1 happens, the incident photon will trigger stimulated emission of photons from E_2 to E_1. [B1]

The emitted photons have the same energy, phase and plane of polarisation as the incident photon, resulting in lasing. [B1]

(iv) Optical pumping results in both stimulated absorption as well as stimulated emission between the lasing levels E_1 and E_2. [B1]

Since number of atoms in a higher energy state is not more than the number in a lower energy state, population inversion does not happen (or is difficult to achieve) and lasing is not achieved. [B1]

(b) **(i)** Stopping potential is the minimum potential difference between the electrodes in a photoelectric experiment, in which the emitted electrons with the maximum kinetic energy (most energetic) from one electrode are just prevented from reaching the other electrode. [B1]

(ii) **1.** $since\ gradient\ of\ graph = \frac{h}{e}$, [C1]

$h = \left(\frac{0.52-0}{(5.50-4.25)\times10^{14}}\right)(1.6\ \times\ 10^{-19}) = 6.66 \times 10^{-34}$ [A1]

2. $work\ function$

$= hf_0 = (6.63\ \times 10^{-34})(4.25\ \times 10^{14}) \div (1.6\ \times\ 10^{-19})$ [B1]

$= 1.76\ eV$

(iii)

Since $f = \frac{c}{\lambda} = \frac{c}{694\times10^{-9}} = 4.32\ \times 10^{14}$ Hz [C1]

From Fig. 8.2, when $f = 4.32\ \times 10^{14}$ Hz, stopping potential $= 0.030\ V$ [A1]

OR

Using $E_k = eV_s = h\frac{c}{\lambda} - hf_0$,

Since $f = \frac{c}{\lambda} = \frac{c}{694\times10^{-9}} = 4.32\ \times 10^{14}$ Hz

$(1.6\ \times\ 10^{-19})V_s = (6.66 \times 10^{-34})(4.32\ \times 10^{14} - 4.25 \times 10^{14})$

$V_s = 0.0303\ V$

OR

Since energy of photon is 1.79 eV and the work function is 1.76 eV, the stopping potential is $= \frac{1.79\ eV - 1.76\ eV}{e} = 0.03\ V$

(iv) The region below the x-axis shows the situation when the frequency of photon is lower than threshold frequency. [B1]

Since photoelectric effect occurs only when frequency of photon is higher than threshold frequency, it is not necessary to have a graph below the x-axis. (Or no photoelectric effect occurs below the threshold frequency) [B1]

(c) **(i)** Using $E = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{1}{2m}\left(\frac{h}{\lambda}\right)^2$, [C1]

$E = \frac{1}{2(9.11\times10^{-31})}\left(\frac{h}{0.17\times10^{-9}}\right)^2 = 8.35\times\ 10^{-18}$ J

Since loss in electric potential energy = increase in kinetic energy,

$(1.6\ \times\ 10^{-19}\ )V = 8.35\times\ 10^{-18}\ - (6.8)(1.6\ \times\ 10^{-19})$ [C1]

$Voltage = 45.4\ V$ [A1]

(ii) Using $\Delta x \Delta\rho = \frac{h}{2\pi}$, [C1]

$(3.8\ \times\ 10^{-10})\Delta\rho = \frac{h}{2\pi}$

$\Delta\rho = 2.8\ \times\ 10^{-25}\ kg\ ms^{-1}$ [A1]

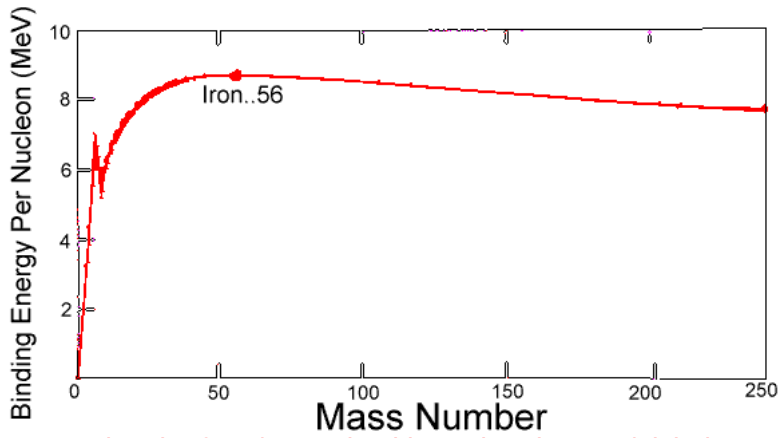
Award maximum of 1 mark if students use

$\Delta x \Delta p_x \geq \frac{\hbar}{2}$ where $\hbar = \frac{h}{2\pi}$

[Turn over

9 **(a)** **(i)** the building up of a larger nucleus from two nuclei of low nucleon number, with the release of energy [B1] [B1]

(ii)



[B1]

Correct sketch of BE/n graph with peak at iron-56/nickel-62.

Deuterium is of lower mass number than iron-56 which is at the peak of the BE/nucleon curve. So when deuterium fuses to become daughter nuclide of larger mass number, such as He or T, the BE/n increases. [B1]

Because the average binding energy per nucleon of the product is greater than that of the two lower mass number nuclei before fusion, a large amount of energy is released during the process. [B1]
OR the total binding energy of the product is greater than that of the reactants, a large amount of energy is release equal to its difference.

(iii) **1.** Particle X: proton [B1]

2. Particle Y: neutron [B1]

(b) **(i)**

$$\text{total BE of reactants} = (2\times1.0073 + 2\times1.0087)u\times c^2 - (2\times2.0141)u\times c^2$$
$$= 3.8\times10^{-3}uc^2$$
$$= 5.6772\times10^{-13}\ \text{J}$$
$$= 3.548\ \text{MeV}$$

$$\text{total BE of products} = (1.0073 + 2\times1.0087)u\times c^2 - (3.0160)u\times c^2$$
$$= 8.7\times10^{-3}uc^2$$
$$= 1.2998\times10^{-12}\ \text{J}$$
$$= 8.124\ \text{MeV}$$

$$\text{energy released} = 8.124 - 3.548$$
$$= 4.576\ \text{MeV}$$
$$= 4.58\ \text{MeV (3sf)}$$

[C1]

OR take the mass of the products (including p) minus the mass of the reactants, and use $E = \Delta mc^2$ [C1]

[A1]

(ii) Strong electric repulsion between the nuclei when they are close to each other. [B1]
Large amount of energy is required to give nuclei sufficient kinetic energy to overcome the repulsion. [B1]

(c) **(i)** the process cannot be speeded up or slowed down by physical means such as changes in pressure or temperature [B1]

(ii) Beta particle [B1]

Gamma rays/particles are not accepted as this reaction specifically does not generate sufficient energy for gamma ray emission. Best answer is still beta particle.

(iii)

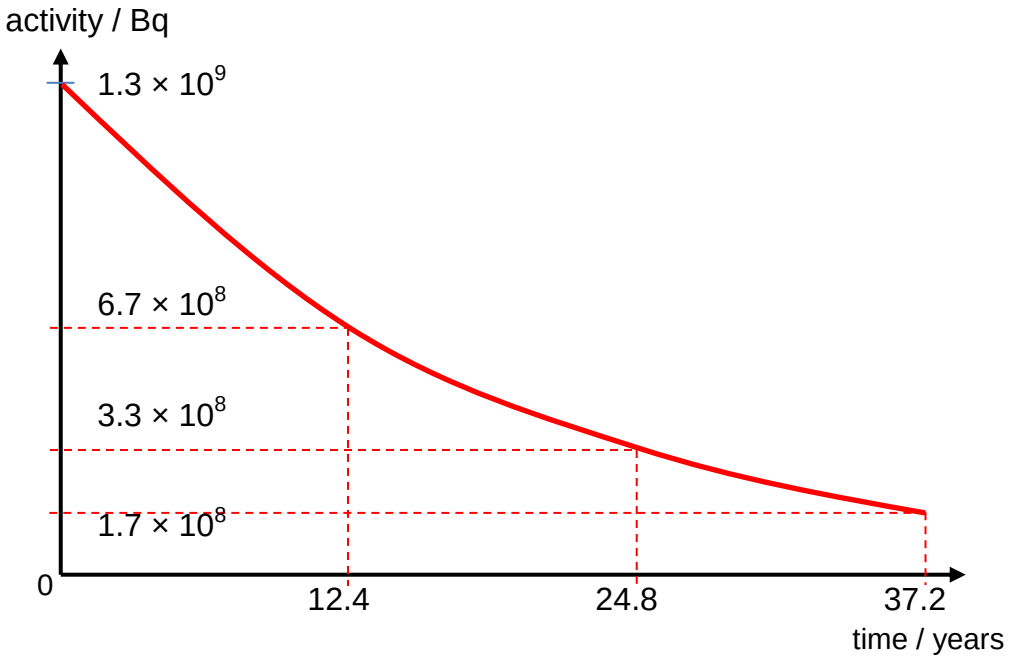


Fig. 9.3

- Correct calculation of half-life [B1]
- Correct calculation of initial activity [B1]
- Correct general shape as a curve, with half initial value of A with every half-life interval. [B1]
- Correct labelling of time and activity values, with at least 3 half-lives duration indicated. [B1]

Additional working:

$$\text{half}-\text{life} = \frac{\ln 2}{0.056} = 12.4 \text{ years}$$

$$\text{decay constant} = \frac{\ln 2}{12.378 \times 365 \times 24 \times 60 \times 60} = 1.775695 \times 10^{-9} \text{s}^{-1}$$

$$A_0 = \lambda N_0 = 1.775695 \times 10^{-9}(7.5 \times 10^{17})$$

$$= 1.33177 \times 10^{9}$$

$$A1HL = 6.65886 \times 10^{8}$$

$$A2HL = 3.32943 \times 10^{8}$$

$$A3HL = 1.66471 \times 10^{8}$$

[Turn over

(iv)
- Much more energy is released per nuclear fusion reaction than per fission reaction
- Fusion of deuterium can produce helium-3 instead, which is not radioactive, there is generally less radioactive waste in fusion than fission.
- Deuterium as fuel for fusion is readily obtainable from seawater. Abundance of fuel vs looking for uranium for fission.
- Any of the above – B1

[B1]

(v) High energy β-particles are electrons which may emit *Bremsstrahlung* when the electrons are slowed down in collision with lead container. [B1]

Class	Index Number	Name
15		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2016
Preliminary Examination

PHYSICS, Higher 2 **9646/01**

Paper 1 Multiple Choice **20th September 2016**
1 hour 15 minutes

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 **forty** 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	/ 40

This document consists of **16** printed pages including this page.

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	$= v_o \cos \omega t$
	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	$= R_1 + R_2 + \ldots$
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	$= x_o \sin \omega t$
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	$= \frac{0.693}{t_{1/2}}$

1 Three pairs of physical quantities are listed below:

I. momentum and moment of a force
II. moment of a force and energy
III. specific latent heat and moment of a force

In which of the pairs do the quantities listed below have the same base units?

A I only
B II only
C II and III only
D None of the pairs

2 A student carries out an experiment to determine the gravitational acceleration, using a pendulum, and obtains a value 9.81 m s^{-2}. The uncertainties in the measurements are shown.

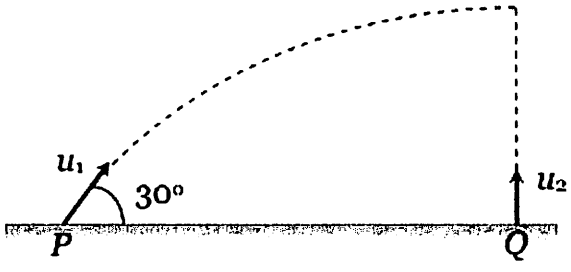
Uncertainty in length L of pendulum = 0.7 %
Uncertainty in period T of pendulum = 0.1 %

The equation for the period T of pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$

How should the answer for gravitational acceleration be stated?

A (9.8 ± 0.1) m s^{-2} **B** (9.81 ± 0.09) m s^{-2}
C (10 ± 8) m s^{-2} **D** (10 ± 9) m s^{-2}

3 A particle **P** is projected with velocity u_1 at an angle of 30° with the horizontal. At the same time, another particle **Q** is thrown vertically upwards with velocity u_2 from a point vertically below the highest point of path of **P**. The necessary condition for the two particles to collide at the highest point is

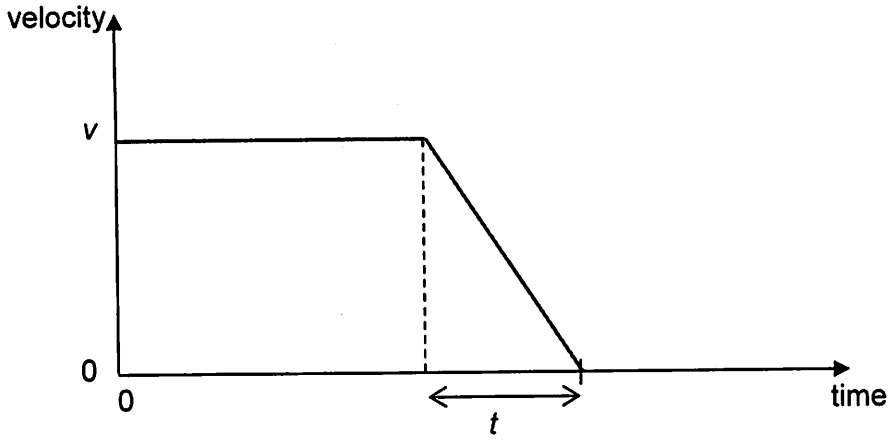


A $u_1 = u_2$ **B** $u_1 = 2u_2$ **C** $u_1 = \frac{u_2}{2}$ **D** $u_1 = 4u_2$

4 A ball, after having fallen from rest under the influence of gravity for 5 s, crashes onto a horizontal glass plate, thereby losing one-third of its velocity. If it then reaches the ground in 3 s, find the height of the plate above the ground.

A 93 m **B** 123 m **C** 142 m **D** 265 m

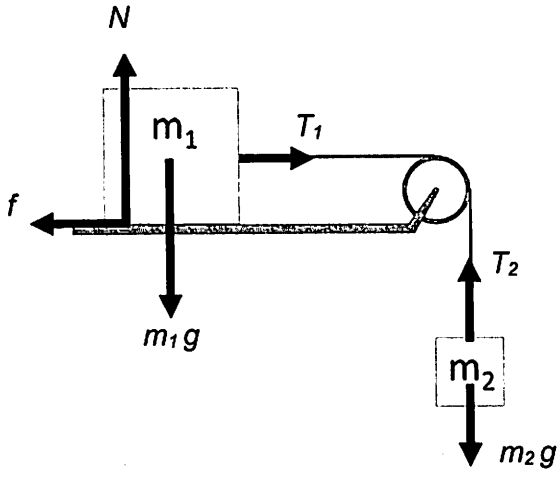
5 A large sandbag of mass m is lifted by a rope attached to a crane. The variation of its velocity with time is as shown below.



What is the change in tension in the rope supporting the sandbag between the time when the sandbag is moving at uniform speed v and the time when the sandbag is decelerating?

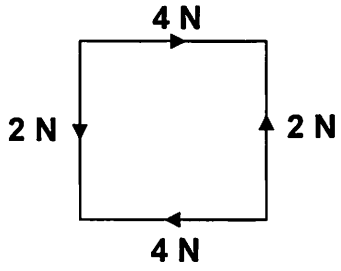
A $\frac{-mv}{t}$ **B** $\frac{-mg}{t}$ **C** $m\left(g-\frac{v}{t}\right)$ **D** $m\left(\frac{v}{t}-g\right)$

6 Two masses m_1 and m_2 are connected by a cord. The tensions, T_1 and T_2 act on m_1 and m_2 respectively. The mass m_1 rests on a horizontal rough surface which exerts a normal force N and friction f on it. The masses remain stationary. Which pair of forces are equal because of Newton's 1st Law and which pair have equal magnitudes?



	Newton's 1st Law	Forces of equal magnitude
A	T_1 and T_2	N and m_1g
B	T_2 and m_2g	f and m_1g
C	m_1g and m_2g	T_1 and T_2
D	f and T_1	T_1 and T_2

7 Forces act along the edges of a square as shown below:



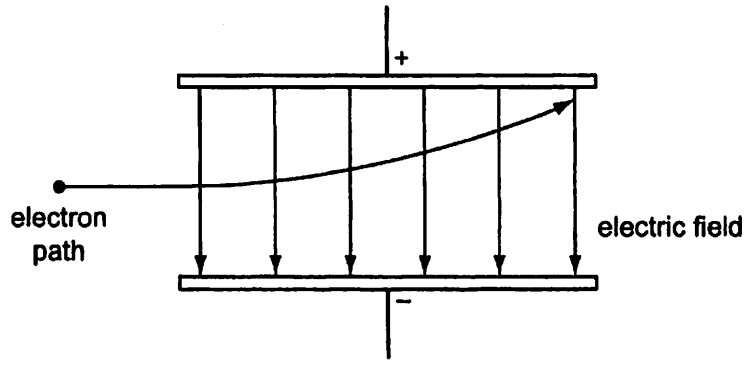
The simplest system to which these forces are equivalent is

A a single force.
B a single couple.
C a resultant force and a couple.
D two couples.

8 An object, immersed in a liquid in a tank, experiences an upthrust. What is the physical reason for this upthrust?

A The difference in the density of the liquid at different depth.
B The difference in the weight of the liquid that was displaced.
C The difference in the pressure of the liquid at different depth.
D The difference in value of *g* in the liquid at different depth.

9 An electron is projected horizontally into the vertical electric field in the space between two horizontal charged plates. The electron follows a curved path as shown.



There are changes to the electron's electric potential energy and to its gravitational potential energy. Which row correctly identifies these changes?

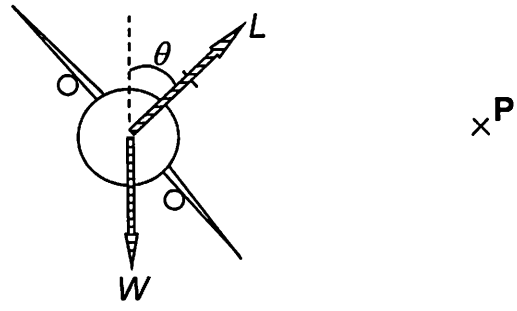
	electric potential energy	gravitational potential energy
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

10 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 $0.50E$ **B** $0.71E$ **C** $0.87E$ **D** E

11 The diagram shows an aircraft, in flight, undergoing a horizontal circular turn of radius 9.00 km about point **P**. It experiences a lift force, L and a gravitational force, W. The aircraft is moving at a speed of 275 m s^{-1}.



What is the angle of tilt, θ?

A 40.6° **B** 49.4° **C** 60.0° **D** 83.2°

12 Two wooden cubes of masses m and $\frac{1}{4}m$ are placed on a turntable. When the turntable rotates at a constant rate, both cubes remain stationary relative to the turntable. If the cube of mass m is at a distance r from the centre of the turntable, what is the corresponding distance for the lighter cube? The frictional force acting on each cube is proportional to its mass.

A r **B** $2r$ **C** $3r$ **D** $4r$

13 For points outside a uniform sphere of mass M, the gravitational field is the same as that of a point mass M at the centre of the sphere. The Earth may be taken to be a uniform sphere of radius r and density ρ.

How is the gravitational field strength g at its surface related to these quantities and the gravitational constant G?

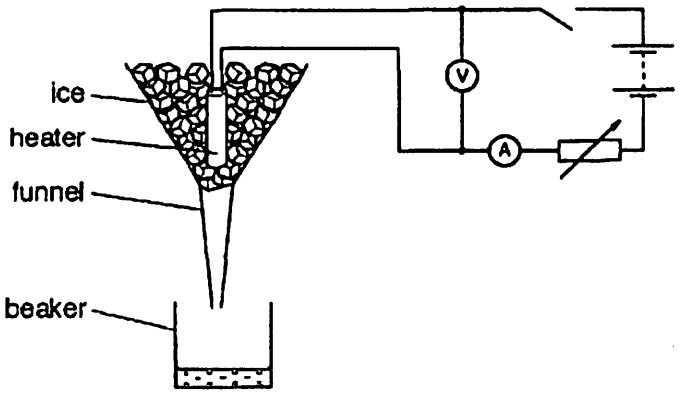
A $g = \frac{G\rho}{r^2}$ **B** $g = \frac{3G}{4\pi r\rho}$

C $g = \frac{4\pi r\rho G}{3}$ **D** $g = \frac{4\pi r^2\rho G}{3}$

14 A satellite orbiting the Earth is moved from one stable orbit to another with a smaller radius. Which of the following statements is true?

A The linear speed of the satellite increases.
B The angular speed of the satellite remains constant.
C The gravitational force acting on the satellite decreases.
D The gravitational potential energy of the satellite increases.

15 A student sets up the apparatus below in order to determine a value for the specific latent heat of fusion of ice.



The power of the heater is 300 W. Before the heater is switched on, 5 g of water is collected from the melting ice in 1 minute. When the heater is switched on, the mass of water collected from the melting ice in 1 minute is 80 g. The specific latent heat of fusion of ice, in $J\,g^{-1}$ is

A 4 **B** 225 **C** 240 **D** 375

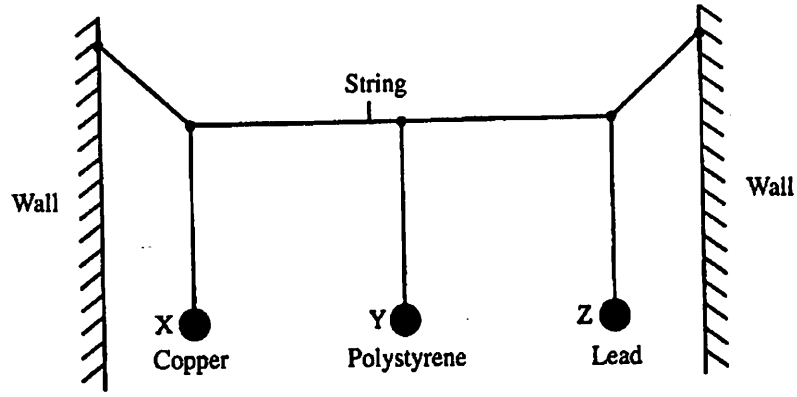
16 Two identical vessels contain two different gases **X** and **Y** with molecular mass m_x and m_y respectively. The absolute temperature of gas **X** is twice that of gas **Y** and the root-mean-square speed of the molecules in **X** is three times that of the molecules in **Y**. What is the value of $\frac{m_X}{m_Y}$?

A $\frac{2}{3}$ **B** $\frac{2}{9}$ **C** $\frac{3}{2}$ **D** $\frac{9}{2}$

17 A particle oscillates with simple harmonic motion along a line with a maximum speed v_0. When the displacement of the particle is half of its amplitude, its speed is

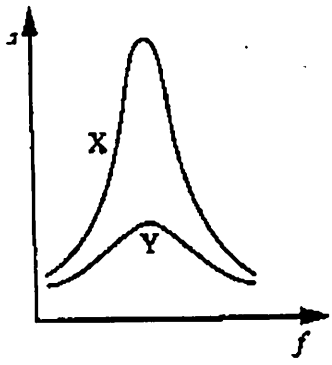
A $\frac{1}{4}v_0$. **B** $\frac{1}{2}v_0$. **C** $\frac{3}{4}v_0$. **D** $\frac{\sqrt{3}}{2}v_0$.

18 The figure below shows two simple pendulums **X** and **Y** having the same lengths and same bob sizes and a simple pendulum **Z** whose length can be varied.

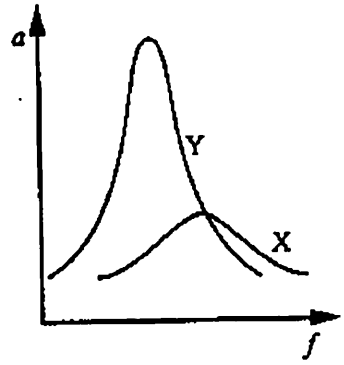


The pendulum **X** and pendulum **Y** will oscillate after the pendulum **Z** is set into oscillations in a plane parallel to the wall. Which of the graphs below shows the variation of the amplitude *a* for the pendulum **X** and pendulum **Y** with frequency *f* of the pendulum **Z** when the length of pendulum **Z** is varied?

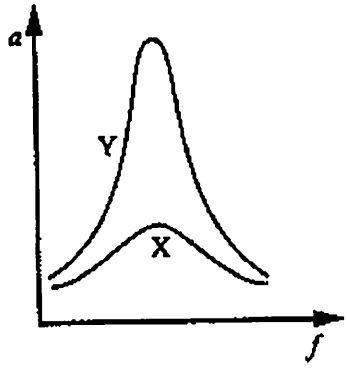
A



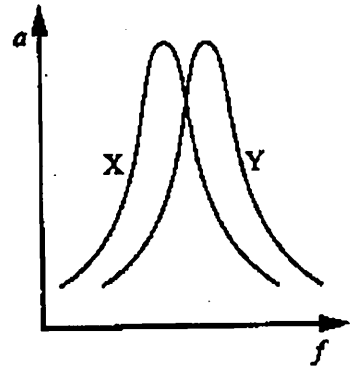
B



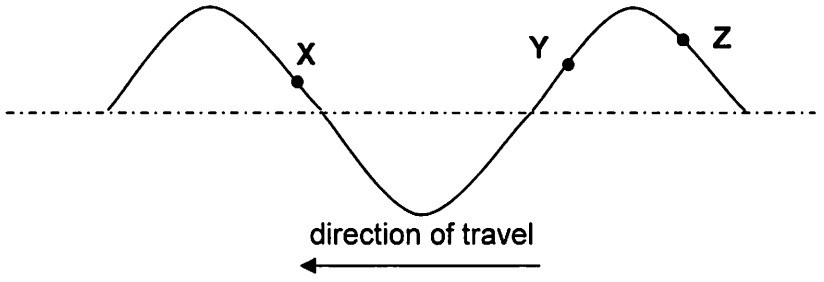
C



D



19 The diagram below shows an instantaneous position of a string as a transverse progressive wave travels along it from right to left.



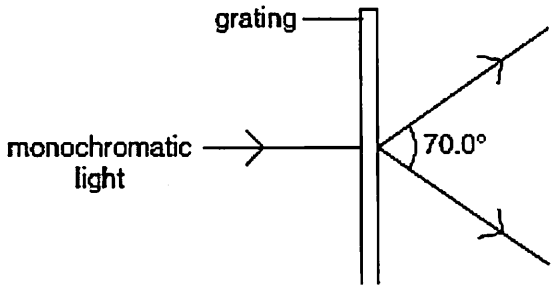
Which of the following correctly shows the directions of the velocities of the points **X**, **Y** and **Z** on the string?

	X	Y	Z
A	left	left	left
B	left	right	left
C	down	up	down
D	up	down	up

20 A plane wave of amplitude A is incident on a surface of area S placed so that it is perpendicular to the direction of travel. The energy per unit time reaching the surface is E. The amplitude of the wave is increase to $2A$ and the area of the surface is reduced to $\frac{1}{2}S$. How much energy per unit time reaches this smaller surface?

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

21 A diffraction grating is used to measure the wavelength of monochromatic light, as shown in the diagram.



The spacing of the slits in the grating is 1.00×10^{-6} m. The angle between the first order diffraction maxima is 70.0°

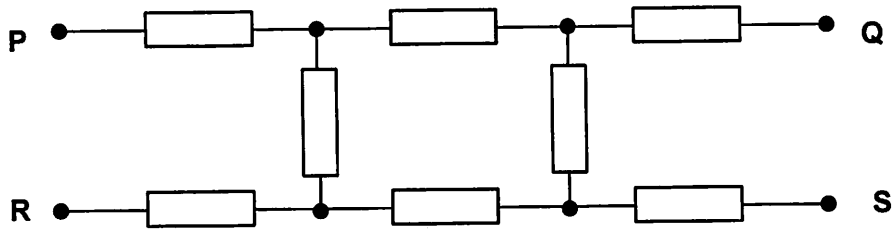
What is the wavelength of the light?

A 287 nm **B** 470 nm **C** 574 nm **D** 940 nm

22 Radiowaves are diffracted by large objects such as buildings whereas light is not noticeably diffracted. Why is this?

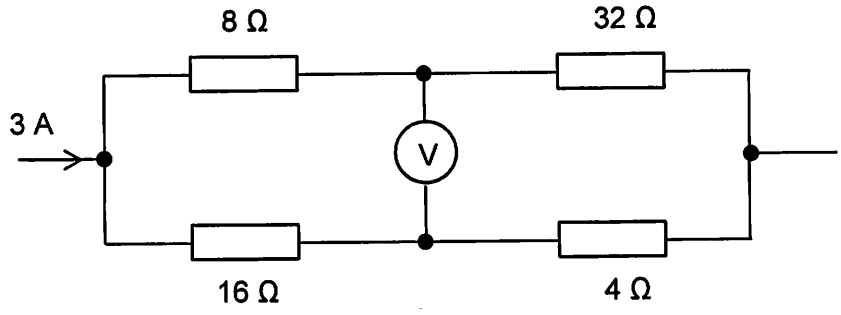
A Radiowaves are unpolarised whereas light is polarised.
B The wavelength of light is much smaller than the wavelength of radiowaves.
C The wavelength of light is much greater than the wavelength of radiowaves.
D Radiowaves are coherent whereas light is normally not coherent.

23 What is the equivalent resistance of the circuit shown in the figure below between points **P** and **S**? Each resistor has a similar resistance of 10 Ω.



A 10 Ω B 20 Ω C 30 Ω D 40 Ω

24 In the following circuit, the voltmeter reading is



A 0 V B 8 V C 12 V D 24 V

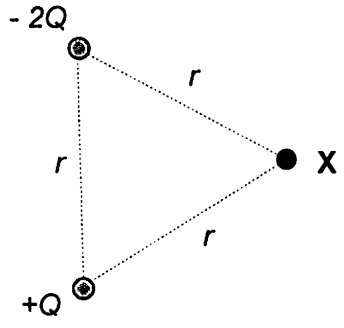
25 Under what circumstances will the resistance of a resistor always be equal to the reciprocal of the gradient of its I-V characteristics graph?

A When the graph is a straight line.
B When the graph cuts through the origin.
C When the graph obeys Ohm's Law.
D Never.

26 A variable resistor is connected across the terminals of a cell which has internal resistance. As the resistance of the variable resistor is gradually increased, what are the effects on the terminal potential difference as well as the power wasted in the internal resistance of the cell?

	Terminal potential difference	Power wasted in the cell
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

27 Two point charges of charged - 2*Q* and +*Q* are arranged at two corners of an equilateral triangle of side *r* in vacuum.



What can be deduced about the electric potential *V*, and the magnitude and direction of electric field strength *E* at point **X**?

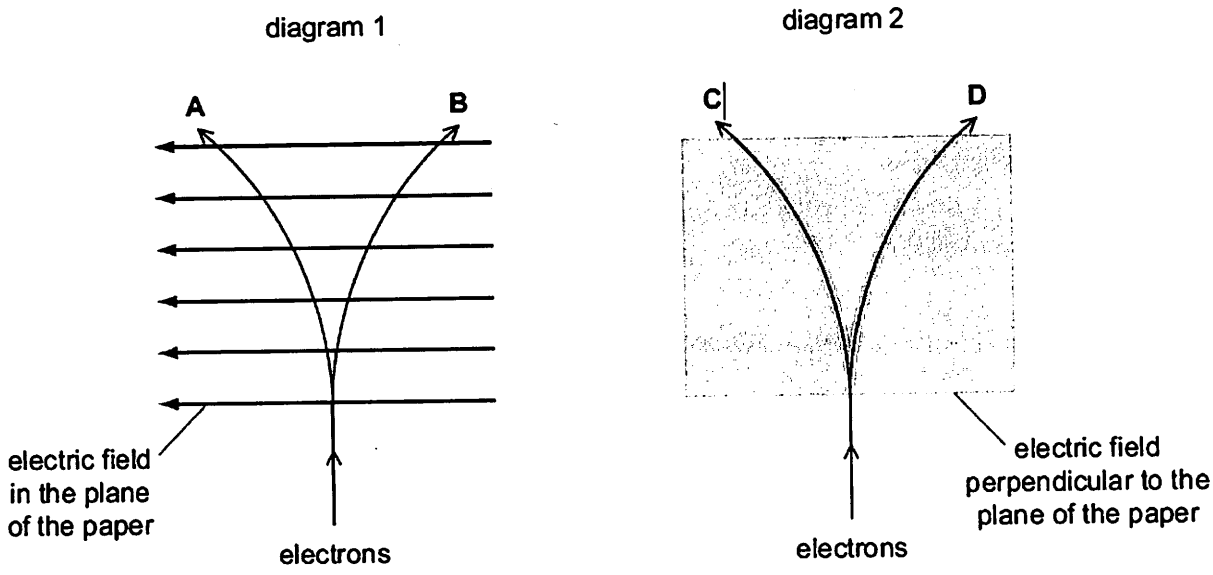
	V	magnitude of *E*	direction of *E*
A	$-\frac{Q}{4\pi\varepsilon_0 r}$	$\frac{Q}{4\pi\varepsilon_0 r^2} < \lvert\vec{E}\rvert < \frac{3Q}{4\pi\varepsilon_0 r^2}$	←
B	$-\frac{2Q}{4\pi\varepsilon_0 r}$	$\lvert\vec{E}\rvert < \frac{3Q}{4\pi\varepsilon_0 r^2}$	→
C	$-\frac{Q}{4\pi\varepsilon_0 r}$	$\lvert\vec{E}\rvert < \frac{Q}{4\pi\varepsilon_0 r^2}$	←
D	$-\frac{Q}{4\pi\varepsilon_0 r}$	$\lvert\vec{E}\rvert = \frac{Q}{4\pi\varepsilon_0 r^2}$	→

28 A beam of electrons is directed into an electric field and is deflected by it.

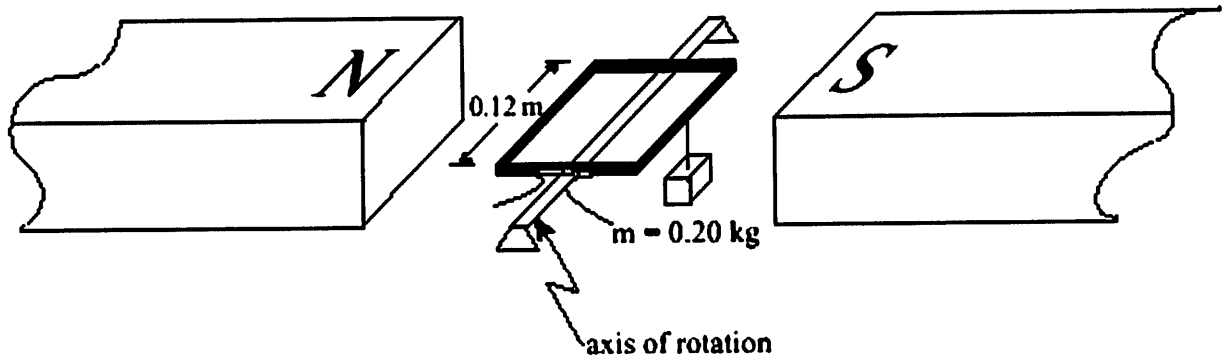
Diagram 1 represents an electric field in the plane of the paper.
Diagram 2 represents an electric field directed perpendicular to the plane of the paper.

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 the electrons inside the field?



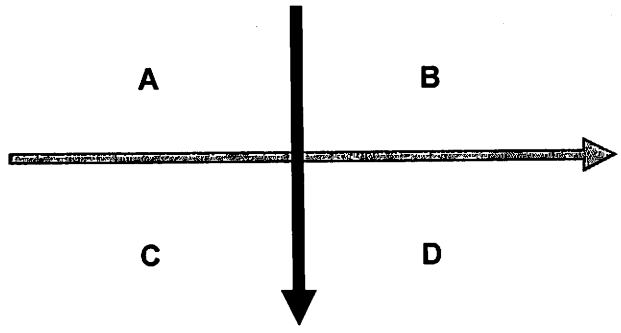
29 A 35 loop square coil 0.12 m on a side is positioned in a 0.050 T magnetic field. A 0.20 kg mass is suspended from one side of the coil as shown in the diagram below.



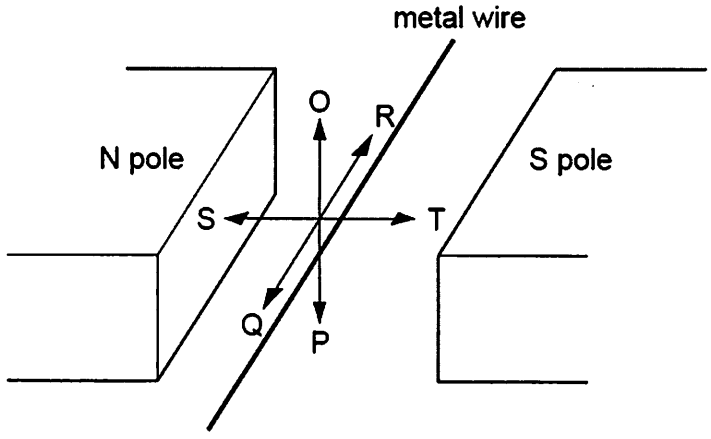
How much current must pass through the coil in order for the coil to remain horizontal?

A 2.3 A **B** 4.7 A **C** 9.3 A **D** 330 A

30 Two wires carry current as shown below. One wire is slightly above the other. Which region has the strongest magnetic field pointing out of the page?



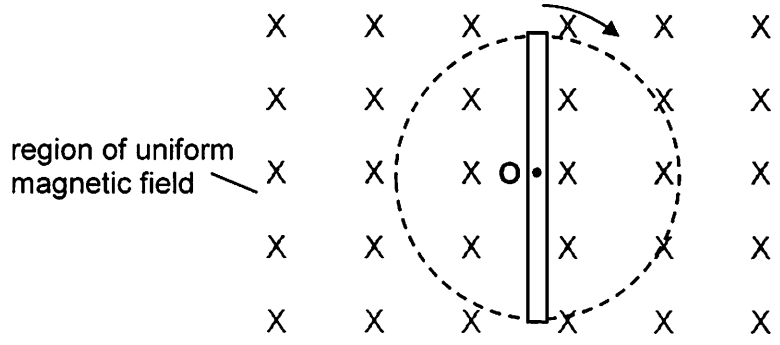
31 A metal wire is placed between the poles of a magnet. The wire can be moved in each of three directions OP, QR and ST.



In which direction or directions must the wire be moved to induce an e.m.f. across the ends of the wire?

A OP only **B** OP or ST **C** QR **D** ST only

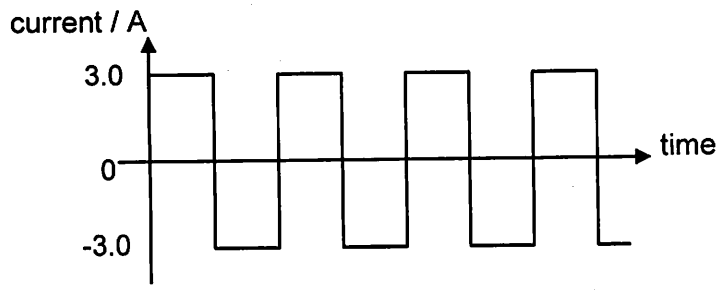
32 An aluminium rod of length 1.2 m spins at a constant rate of 20 revolutions per second about its centre O in a region of uniform magnetic field of flux density 0.25 T.



What is the magnitude of the induced e.m.f. between the ends of the rod?

A 0 V **B** 5.7 V **C** 23 V **D** 45 V

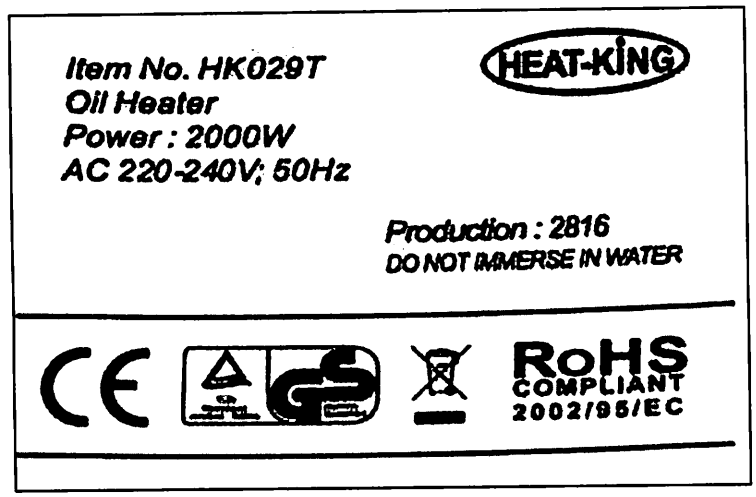
33 The graph shows a rectangular waveform with a peak current of 3.0 A.



In order to obtain the same r.m.s. current with the same frequency as the waveform shown, a sinusoidal current should have a peak value of

A 2.1 A **B** 3.0 A **C** 4.2 A **D** 6.0 A

34 An electric oil heater has the following label as shown below. Which of the following is a probable expression of the current that passes through the oil heater when used in Singapore?



A $I = 8.33 \sin (314\ t)$
B $I = 11.8 \sin (314\ t)$
C $I = 14.1 \sin (375\ t)$
D $I = 16.0 \sin (375\ t)$

35 What is the de Broglie wavelength associated with a proton having kinetic energy 2.1×10^{-16} J?

A 3.2×10^{-18} m
B 7.9×10^{-13} m
C 1.3×10^{12} m
D 3.1×10^{17} m

36 Which of the following statements concerning the X-ray spectrum is false?

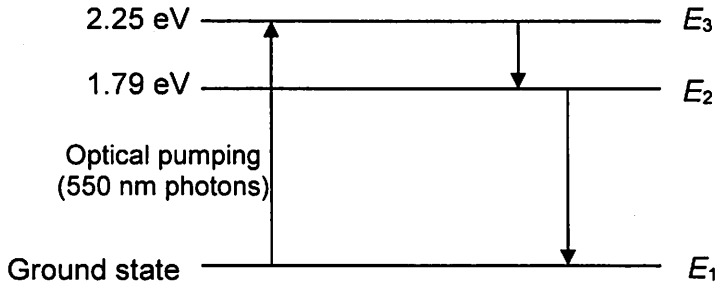
A Some of the sharp peaks in the spectrum will disappear if the potential applied to accelerate the bombarding electrons is decreased.

B In unit time, fewer photons are emitted due to the deceleration of the bombarding electrons as compared to those photons emitted as a result of electrons knocking deep-lying atomic electrons.

C Apart from producing X-rays, some of the energy of the bombarding electrons goes into producing heat in the target material.

D When the potential applied to accelerate the bombarding electrons is increased, both continuous and line parts of the spectrum increase in intensity.

37 In a ruby laser, light of wavelength 550 nm from a xenon flash lamp is used to excite the chromium (Cr) atoms in the ruby from ground state E_1 to state E_3. In subsequent de-excitations, laser light is emitted. Which of the following statements regarding this laser is *incorrect*?



A Electrons can spontaneously de-excite from E_2 to E_1.

B E_3 is the metastable state because having a longer lifetime than a normal excited state, the metastable state allows the accumulation of excited electrons, resulting in population inversion and net light production.

C E_2 is the metastable state because it will not result in stimulated emission caused by the 550 nm photons used in optical pumping and so allows excited electrons to accumulate on it.

D The transition from E_2 to E_1 produces laser light.

38 Why is laser light coherent?

A The excited electrons are in a metastable state.
B The system is in a state of population inversion.
C Stimulated emission causes the emitted photon and the incident photon to be of the same phase.
D Photons of the same energy as that of the incident photons are emitted when the electrons transit down from a higher energy level.

39 A nuclide Y has the notation ${}^{a}_{b}Y$.

If M is the mass of nucleus, m_1 is the mass of a proton and m_2 is the mass of a neutron, what is the binding energy per nucleon of this nucleus?

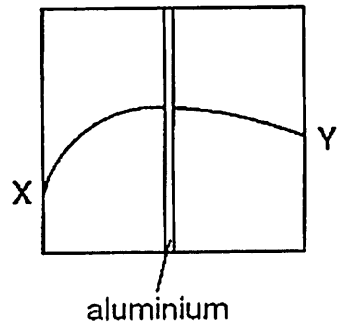
A $[bm_2 + am_1 - M]\, c^2$

B $[bm_1 + am_2 - M]\, c^2 / (a + b)$

C $[bm_2 + (b - a)\, m_1 - M]\, c^2 / b$

D $[bm_1 + (a - b)\, m_2 - M]\, c^2 / a$

40 A radioactive source emits radiation which enters an evacuated region and follows a curved path in the plane of the paper as shown. The region has a uniform magnetic field perpendicular to the plane of the paper and is divided into two by a sheet of aluminium 1 mm thick.



Which of the following correctly describes the type of radiation and its point of entry?

	type of radiation	point of entry
A	Alpha	X
B	Alpha	Y
C	Beta	X
D	Beta	Y

Class	Index Number	Name
15		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2016
Preliminary Examination

PHYSICS, Higher 2 **9646/02**

Paper 2 Structured Questions **13th September 2016**
1 hour 45 minutes

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	/ 8
2	/ 10
3	/ 11
4	/ 8
5	/ 10
6	/ 13
7	/ 12
Total	/ 72

This document consists of **19** printed pages including this page.

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	$= u\,t + \frac{1}{2}\,a\,t^2$
	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,	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	$= v_o \cos \omega t$
	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	$= R_1 + R_2 + \ldots$
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	$= x_o \sin \omega t$
transmission coefficient,	T	$\alpha \exp(-2\,k\,d)$
		where $k = \sqrt{\frac{8\pi^2 m (U - E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{1/2}}$

1 **(a)** A pendulum is fixed onto the ceiling of a train carriage as shown in **Fig. 1.1.** If the train is now cruising at constant speed towards the right as indicated, draw in **Fig. 1.2** below and explain the resultant position of the pendulum.

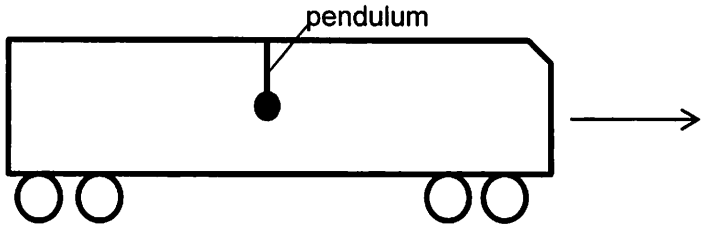


Fig. 1.1

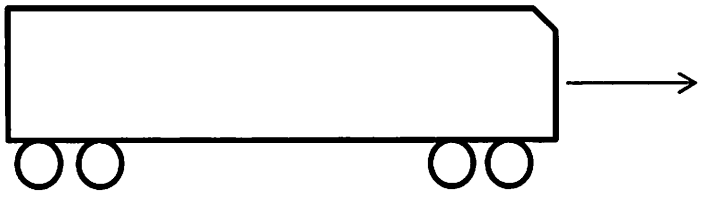


Fig. 1.2

.....

.....

.....[2]

(b) A ladder, illustrated by the bold line, is resting inclined against a wall as shown in **Fig. 1.3** below

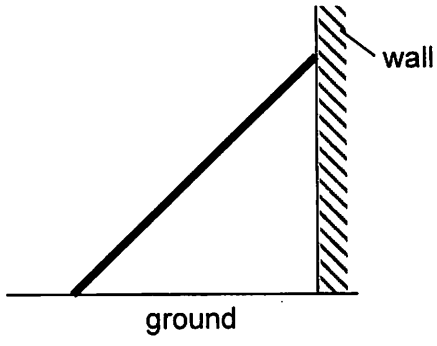


Fig. 1.3

A student claims that if the wall is frictionless but the ground is rough, the ladder cannot hold in its current position. Comment on his claim.

.....

.....

.....

.....[2]

(c) A hungry bear weighing 700 N walks out on a beam in an attempt to retrieve a basket of food hanging at the end of the beam as shown in **Fig. 1.4** below. The beam is uniform, weighs 200 N and is 6.00 m long. The basket of food weighs 80 N.

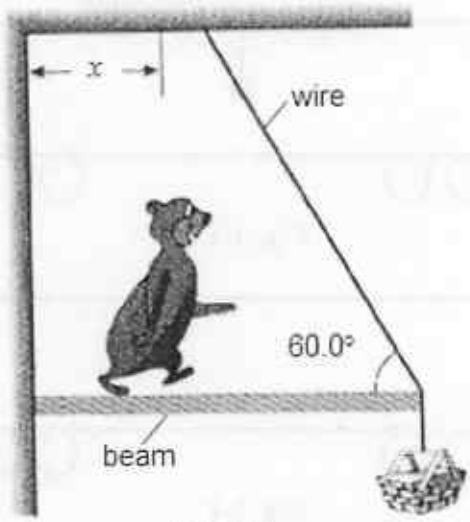


Fig. 1.4

(i) If the wire can withstand a maximum tension of 900 N, calculate x, the maximum distance that the bear can walk before the wire breaks.

x = ... m [2]

(ii) In his excitement to reach the food, the hungry bear leapt instead of walking gently before reaching x, and the wire was seen to break. Explain why this was so.

.....

.....

.....[2]

2 (a) (i) Explain the concept of *absolute zero* on the thermodynamic temperature scale.

.....

.....[1]

(ii) State what is meant by an *ideal* gas.

.....

.....

.....

.....[3]

(b) Two vessels **X** and **Y** are connected by a tube of negligible volume, as shown in **Fig. 2.1**.

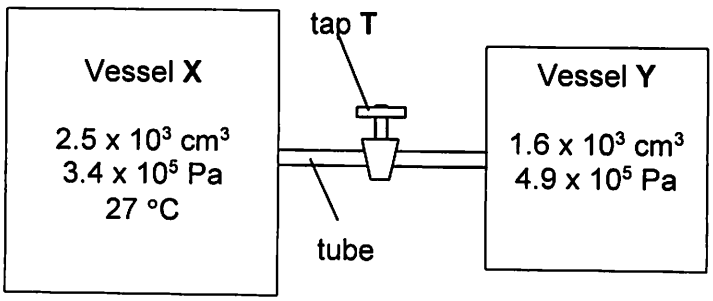


Fig. 2.1

Initially, tap **T** is closed. The vessels contain an ideal gas at different pressures.

(i) Vessel **X** has a constant volume of 2.5 x 10^3 cm^3 and contains gas at pressure 3.4 x 10^5 Pa and temperature 27 °C.

Show that vessel **X** contains 0.34 mol of gas. [1]

(ii) Vessel **Y** has a constant volume of 1.6 x 10^3 cm^3 and contains 0.18 mol of gas. When tap **T** is opened, the pressure of the gas in both vessels is 4.0 x 10^5 Pa. No thermal energy enters or leaves the gas. Determine the final equilibrium temperature of the gas.

temperature = ... K [2]

(iii) Use the first law of thermodynamics to explain why the temperature of the gas in vessel **X** changes when tap **T** is opened.

.....

.....

.....

.....

.....[3]

3 (a)

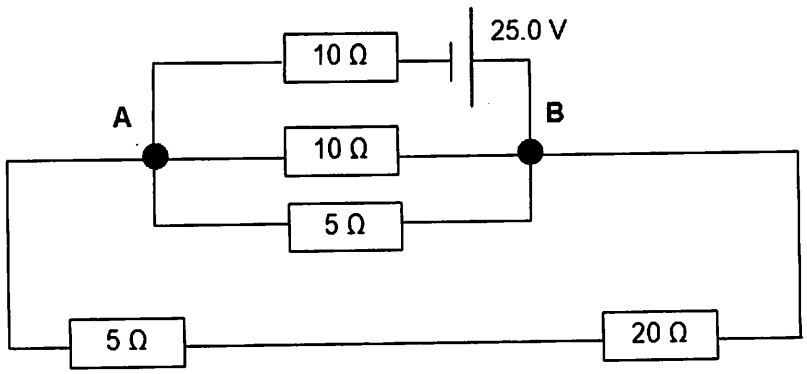


Fig. 3.1

Determine from **Fig. 3.1**,

(i) the effective resistance of the circuit, and

effective resistance =.....Ω [2]

(ii) the potential difference between points **A** and **B**.

potential difference =.....V [2]

(b) A potentiometer circuit is set up as shown in **Fig. 3.2** below. The e.m.f. of the cells are as indicated and the galvanometer **G** shows a null deflection. The resistance wire **AB** has a length of 150 cm and resistance of 50 Ω. The resistor R_1 has a value of 1 kΩ.

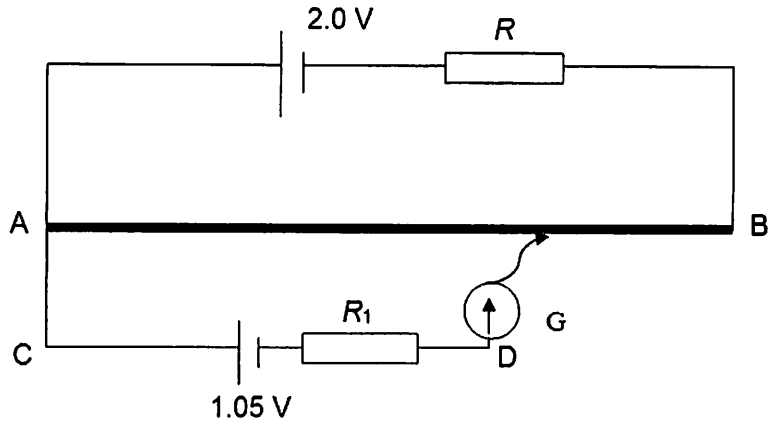


Fig. 3.2

(i) The potential difference per metre along the 150 cm long wire **AB** is 1.0 V m^{-1}. Calculate the value of R.

R =..... Ω [2]

(ii) State the direction of the current flow between **A** and **C** in **Fig. 3.2** when the jockey is shifted to the right.

.....[1]

(iii) State and explain what happens to the balance point when a thinner wire of the same length and resistivity is used.

.....

.....

.....[2]

(c) Explain why some incandescent (filament) lamps burn out just as they are switched on.

.....

.....

.....[2]

4 (a) **Fig. 4.1** shows two identical bar magnets being released from the same height at the same instant. The first magnet falls through coil **A**, which is connected in series with a lamp. The second magnet falls through an identical coil, coil **B**, which is left unconnected.

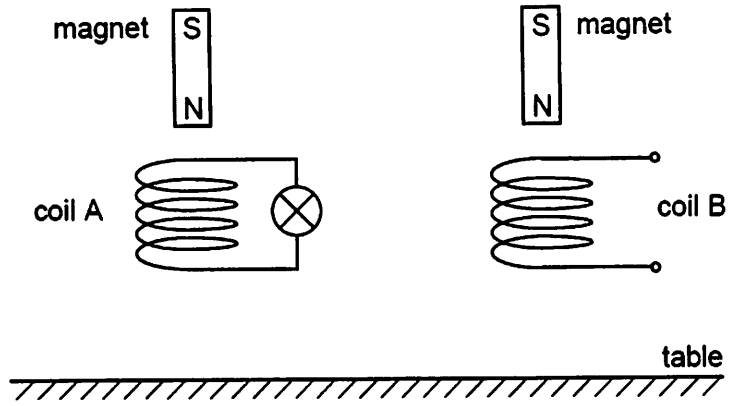


Fig. 4.1 (not to scale)

The magnet falling through coil **B** reaches the table before the magnet falling through coil **A**.

Explain these observations, making reference to both situations in your answer.

.....

.....

.....

.....

.....

.....

.....

.....

.....[5]

(b) The terminals of coil **B** are connected to a data-logger which records the induced e.m.f. E as the magnet falls through the coil.

Fig. 4.2 is a graph showing how the e.m.f. varies with time.

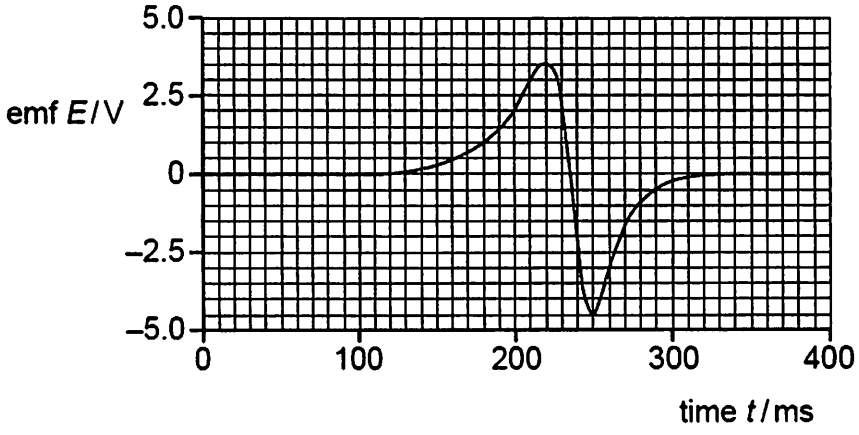


Fig. 4.2

(i) The coil has 400 turns. Use data from the graph to determine the rate of change of flux at time t = 200 ms.

rate of change of flux = ... Wb s^{-1} [1]

(ii) The peak e.m.f. values are + 3.5 V and – 4.5 V.

Explain, in terms of the motion of the magnet, why these two values are different.

.....

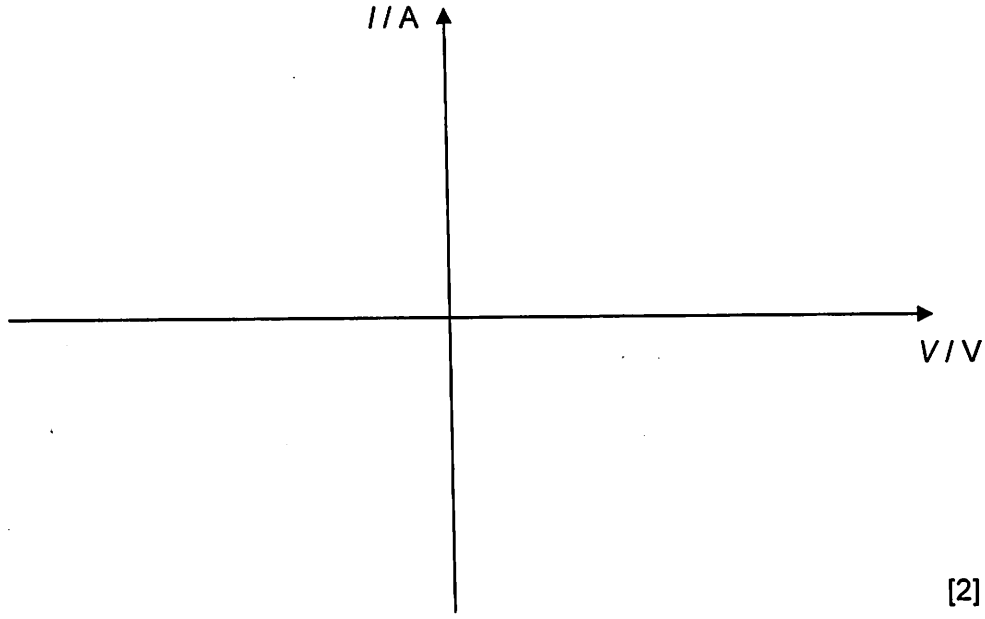
.....

.....

.....[2]

5 **(a)** In 1887, Heinrich Hertz observed that when a metallic surface is exposed to monochromatic light, electrons may be emitted. He published these observations in the journal *Annalen der Physik* and it eventually came to be known as the photoelectric effect.

(i) Sketch a graph on the axes below to show the photocurrent-potential (*I*-*V*) characteristic obtained from a photoelectric effect experiment. Indicate the stopping potential on your graph.



[2]

(ii) A student wants to increase the magnitude of the stopping potential in the experiment by increasing the intensity of the incident radiation. This suggestion was disproved in an experiment conducted in his school's laboratory.

1. Explain why stopping potential is independent of the intensity of the incident radiation.

.....

.....

.....

.....

.....[2]

2. Sketch, on the graph in **(i)**, the actual effect of increasing the intensity of the incident light. [1]

3. Suggest what he should change instead to achieve an increase in stopping potential.

.....[1]

(b) **Fig. 5.1** 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 when the beam is passed through a diffraction grating. **Fig. 5.2** shows some energy levels of the sodium atom.

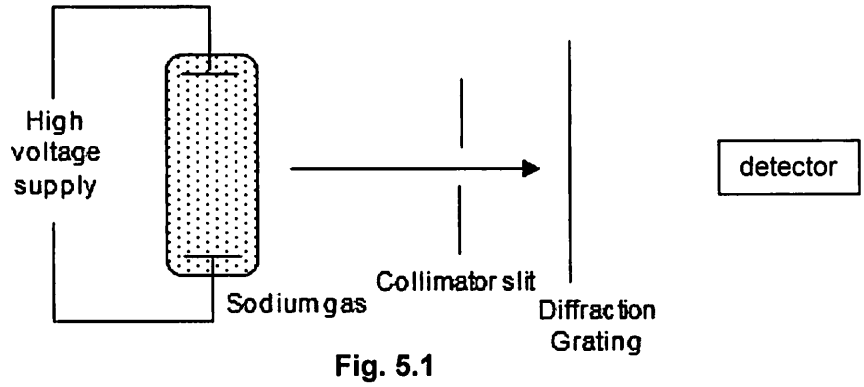


Fig. 5.1

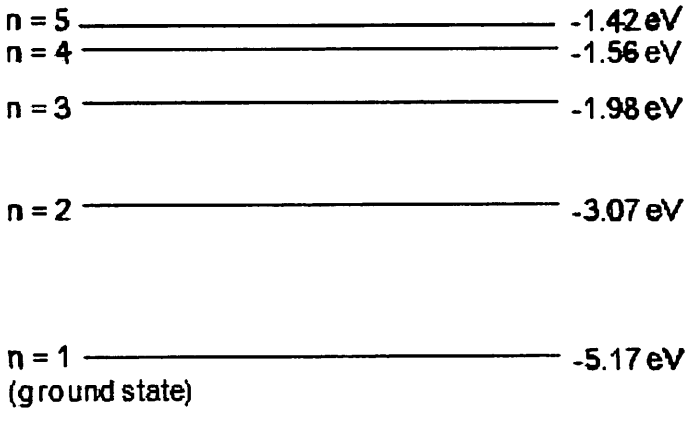


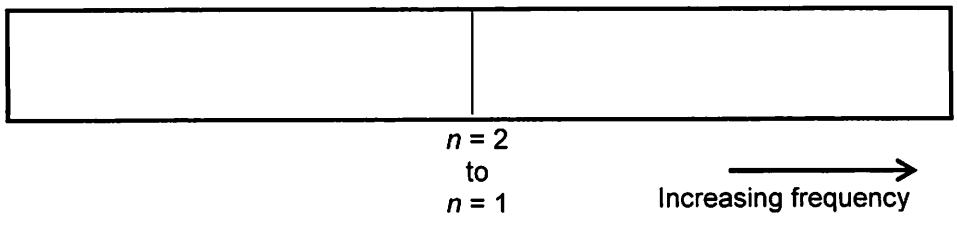
Fig. 5.2

Given that the bombarding electrons have a kinetic energy of 3.70 eV,

(i) Deduce the number of spectra lines which might be detected.

number of spectra lines = ... [1]

(ii) Sketch the positions of the lines on the spectrum below, indicating clearly the various transitions. The line due to the transition from $n = 2$ to $n = 1$ has been drawn for you.



[2]

(iii) Determine the range of kinetic energy of the recoiling electrons after they have excited the sodium atoms.

range: ..... eV ≤ KE ≤ .....eV [1]

6 (a) State what is meant by

(i) forced oscillations and

.....

.....[1]

(ii) resonance.

.....

.....

.....[2]

(b) **Fig. 6.1(a)** shows an alternating signal generator (with varying frequency) connected to a length of copper wire. **Fig. 6.1(b)** is observed in the wire at a specific frequency.

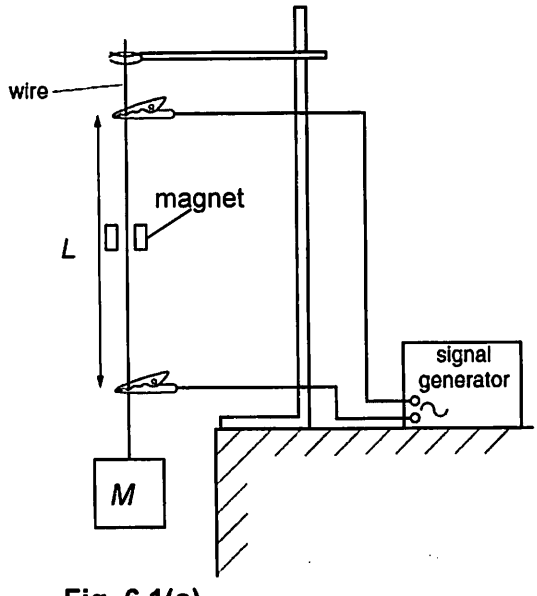


Fig. 6.1(a)

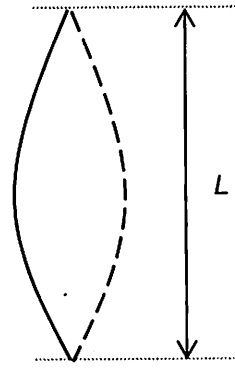


Fig. 6.1(b)

Mass M attached to the copper wire that hangs vertically has a mass of 3.00 kg.

The signal generator is switched on and causes the copper wire to oscillate. The crocodile clips are moved until the length L for the maximum amplitude of oscillation is recorded as shown in **Fig. 6.1(b)**. Length L denotes the length that resonance is observed on the wire.

Fig. 6.2 shows the variation with frequency f of length L.

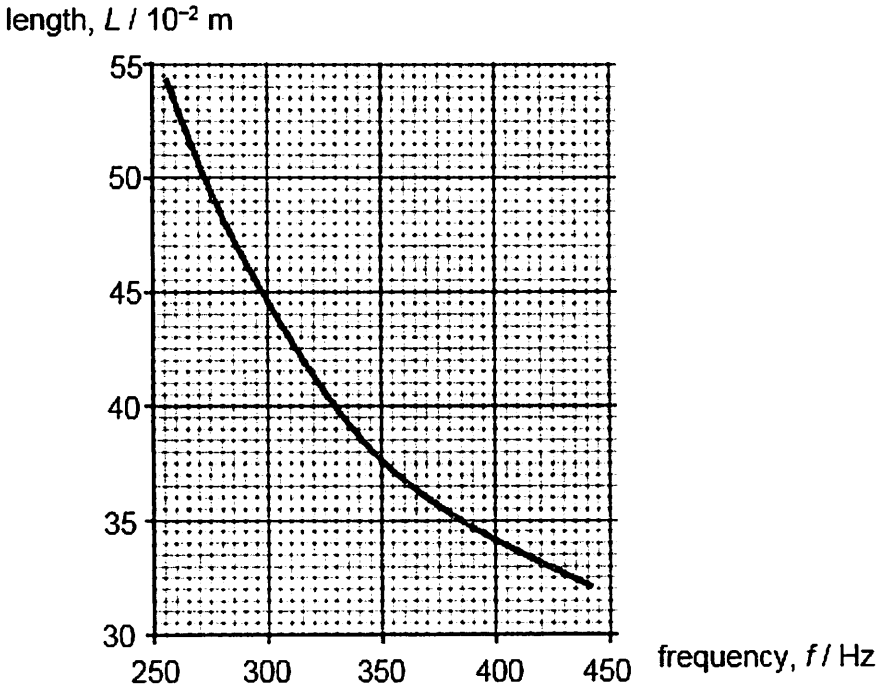


Fig. 6.2

(i) Derive the expression of v in terms of L and f for this mode of resonance (1st harmonic), where v is the speed of the wave in the wire. [2]

(ii) Hence or otherwise, state the general relationship of v, L and f for the nth harmonic.

..... [1]

(c) The variation between f and m is given by the expression

$$f - c = \frac{1}{2L}\sqrt{\frac{mg}{\mu}}$$

where μ and c are constants.
f is the frequency when length of resonant wire is L.
The mass of the load is m.
The constant μ is dependent on the material of the wire used on which resonance is observed.
An experiment is carried out to determine μ. The values of f are determined at L = 40.0 cm for different values of m. **Fig. 6.3** shows the readings obtained.

f / Hz	m / kg	$\sqrt{m}$ / kg$^{\frac{1}{2}}$
318	2.00	1.41
324	2.50	1.58
	3.00	
336	3.50	1.87
341	4.00	2.00
345	4.50	2.12
351	5.00	2.23

Fig. 6.3

(i) Use **Fig. 6.2** to complete **Fig. 6.3** for m = 3.00 kg. [1]

(ii) **Fig. 6.4** is a graph of some of the data in **Fig. 6.3**.

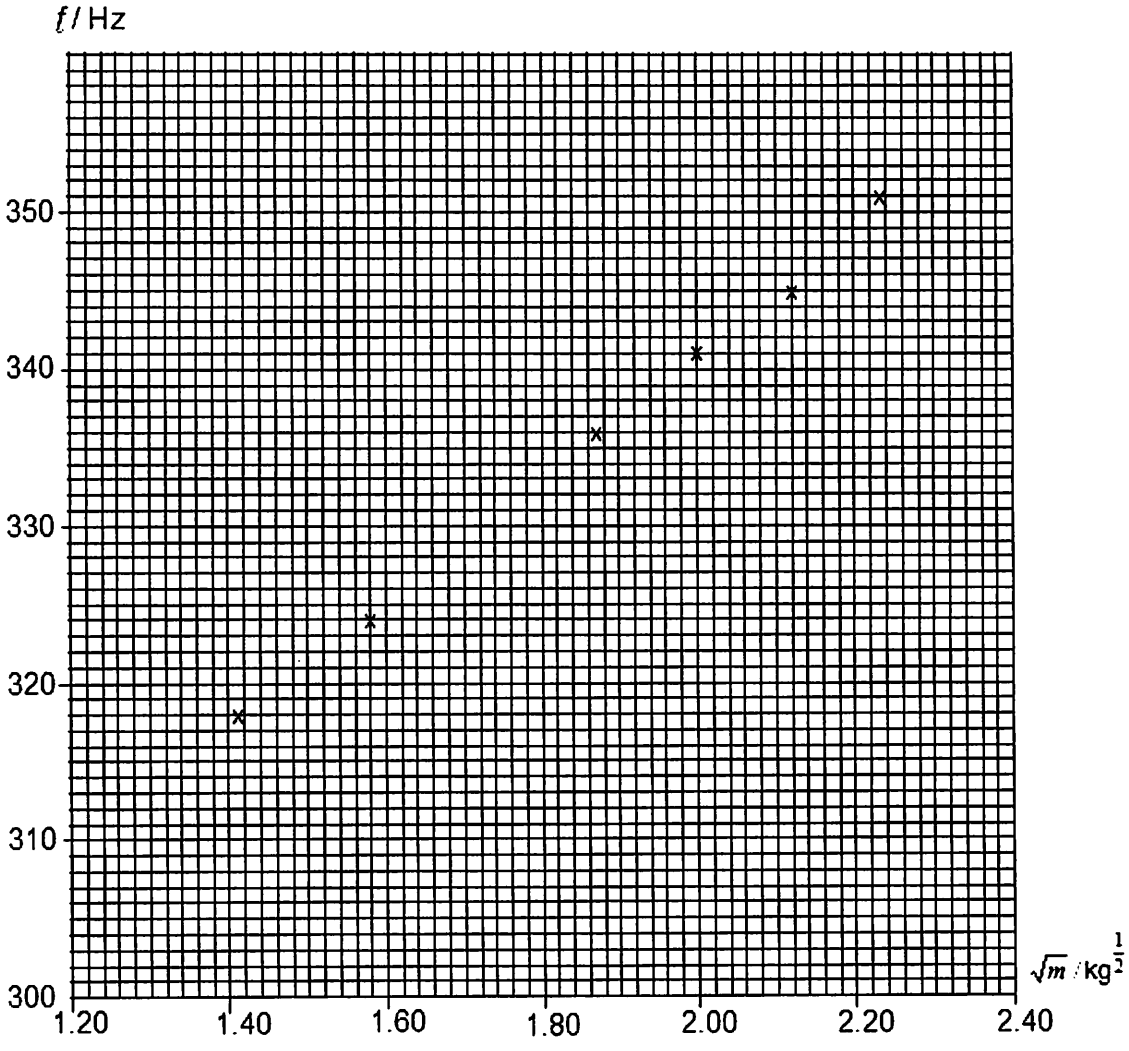


Fig. 6.4

On **Fig. 6.4**,

1. plot the point corresponding to m = 3.00 kg, and

2. draw the line of best fit for all the points. [2]

(iii) Explain why the graph in **Fig. 6.4** supports the expression

$$f - c = \frac{1}{2L}\sqrt{\frac{mg}{\mu}}$$

.....

.....

.....

..... [2]

(iv) Suggest two possible factors that could affect μ.

.....

.....

.....

..... [2]

7 The speed v of water waves depends on the wavelength λ of the waves and the depth d of the water. The following formulas appeared in a scientific journal.

$$v = \sqrt{(g\lambda / 2\pi)} \text{ for deep water, } d > \lambda/2$$

$$v = \sqrt{gd} \text{ for shallow water, } d < \lambda/20$$

In these formulas, g is the acceleration of free fall.

You are provided with a ripple tank fitted with a motorised vibrating bar. You may also use any of the other equipment usually found in a Physics laboratory.

Design a laboratory experiment to test the relationship between v and d for shallow water.

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

(a) the equipment you would use,

(b) the procedure to be followed,

(c) how you would check that the water is sufficiently shallow,

(d) the control of variables,

(e) any precautions that would be taken to improve the accuracy of the experiment.

[12]

Diagram

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Class	Index Number	Name
15		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2016
Preliminary Examination

PHYSICS, Higher 2 **9646/03**

Paper 3 Longer Structured Questions **19th September 2016**
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 **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	
Section A	
1	/ 8
2	/ 8
3	/ 7
4	/ 11
5	/ 6
Section B	
6	/ 20
7	/ 20
8	/ 20
Total	/ 80

This document consists of **23** printed pages including this page.

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	$= u\,t + \frac{1}{2}\,a\,t^2$
	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,	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	$= R_1 + R_2 + \ldots$
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	$= x_o \sin \omega t$
transmission coefficient,	T	$\alpha \exp(-2\,k\,d)$
	where k =	$\sqrt{\frac{8\,\pi^2\,m\,(U - E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{1/2}}$

Section A

Answer **all** questions in the spaces provided.

1 The four graphs in **Fig. 1.1**, plotted against time, show quick changes of different objects. Three of these sketch graphs are possible for ordinary objects and one of them is impossible.

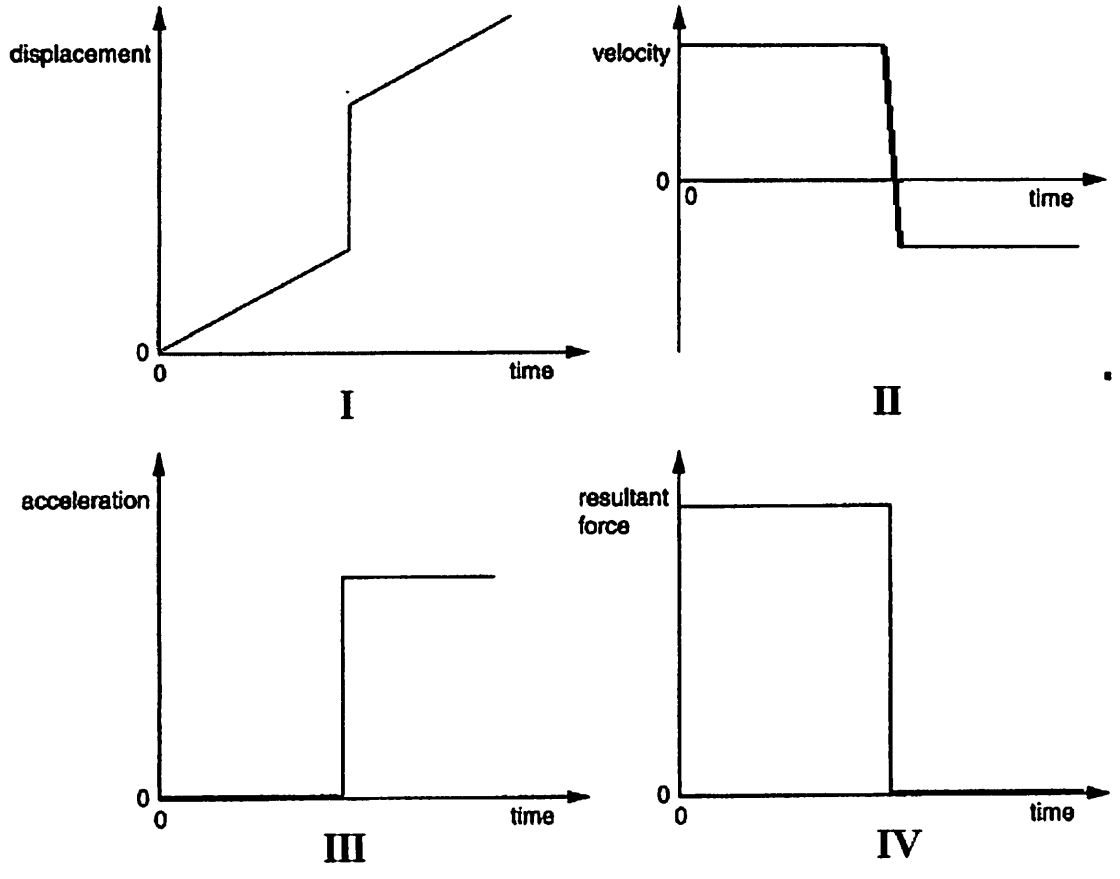

Fig. 1.1

(a) Identify the impossible graph and provide a reason for the selection.

The impossible graph is .....

The graph is impossible because .....

.....

.....[2]

(b) The graph of **Fig. 1.2** shows how g, the acceleration due to gravity, varies with r, the distance from the centre of the Earth.

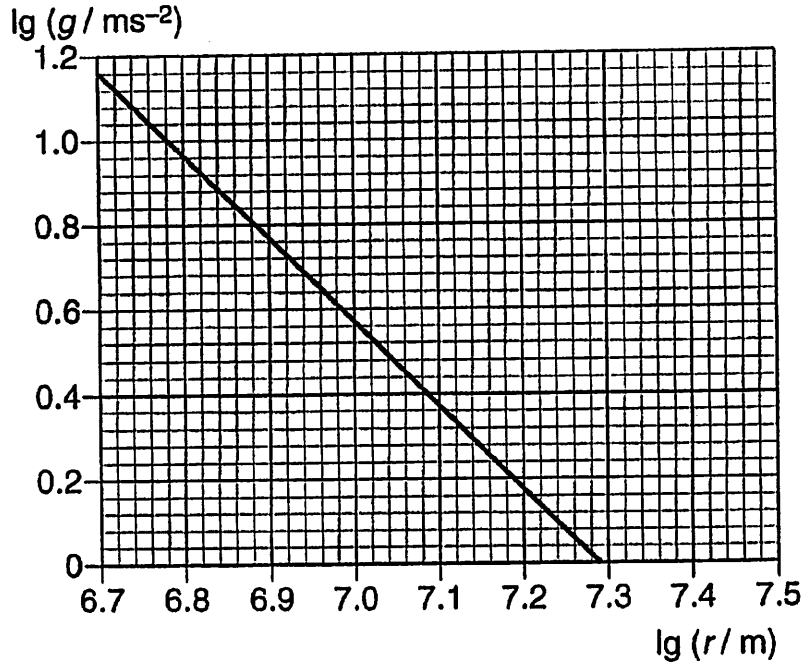

Fig. 1.2

(i) Calculate the gradient of the graph.

gradient = ... [1]

(ii) State what can be inferred from the gradient of the graph calculated in **(i)** with regards to g and r.

.....

.....[1]

(c) A young and reckless driver was speeding in his sports car at a constant speed of 200 km h^{-1} when he drove past a traffic policeman who was already on his motorbike, stationary but in surveillance beside a street lamp. Assuming the policeman then went with an acceleration of 25 m s^{-2}, calculate how much time he took to get alongside this reckless driver.

time = ... s [2]

(d) A lorry changes its velocity from 50 m s^{-1} due East to 30 m s^{-1} due South.

(i) Draw a vector diagram to illustrate the change in velocity. [1]

(ii) Calculate the change in velocity

change in velocity = ...m s^{-1} [1]

2 **(a)** Explain the concept of work.

.....

.....

.....[2]

(b) A table tennis ball falls vertically through air. **Fig. 2.1** shows the variation of the kinetic energy E_k of the ball with distance h fallen. The ball reaches the ground after falling through a distance h_o.

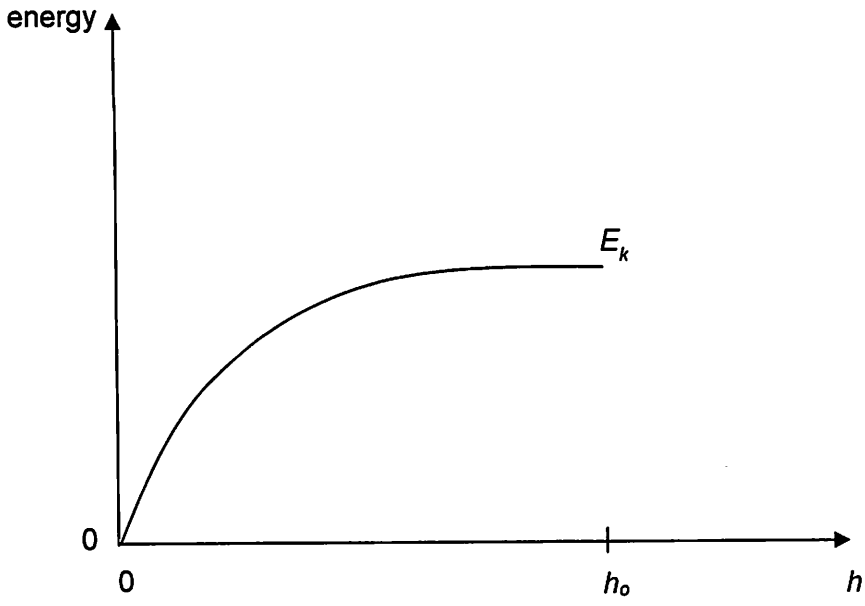

Fig. 2.1

(i) Explain the motion of the ball as shown by **Fig. 2.1**.

.....

.....

.....

.....

.....[3]

(ii) On **Fig. 2.1**, draw a line to show the variation with h of the gravitational potential energy E_p of the ball. At $h = h_o$, the potential energy is zero. [3]

3 **(a)** In understanding a complex oscillating system such as the speaker, it is useful to first consider a simple freely oscillating cone of the speaker. In a particular set-up, the displacement against time graph of its free oscillation is shown in **Fig. 3.1**.

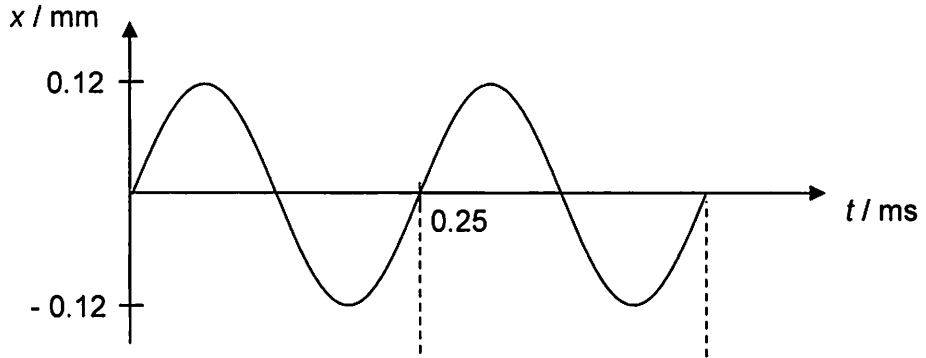

Fig. 3.1



Fig. 3.2

(i) Sketch on the axes in **Fig. 3.2** above, three labelled lines showing how the kinetic energy, potential energy and total energy of the oscillator vary with time. [3]

(ii) Calculate the maximum acceleration of the cone.

maximum acceleration = ... m s^{-2} [2]

(b) Some parents rock their babies to sleep by using a cradle attached to the end of a fixed spring as shown in **Fig. 3.3** below.

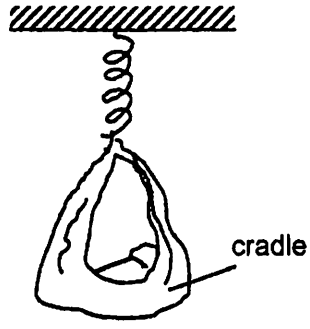

Fig 3.3

A baby is placed in a cradle of negligible mass and given a downward displacement such that it undergoes vertical simple harmonic motion.

Show that the angular frequency of oscillation ω is given by the equation

$$\omega^2 = \frac{k}{m}$$

where m is the mass of the baby and k the force constant of the spring. [2]

4 **(a)** Define *electric potential* at a point.

.....

.....[1]

(b) The magnitude of the potential gradient in an electric field is always equal to that of the electric field strength. Using the concept of work done in moving a charge, show that this is true for a uniform electric field E between two parallel plates a distance d apart when the potential difference between the plates is V.

.....

.....

.....[2]

(c) **Fig. 4.1** shows a full-scale cross-section of the electric field in the region of a charged circular metal rod and a U-shaped metal frame. The dotted lines on the diagram are equipotential lines at labelled potentials.

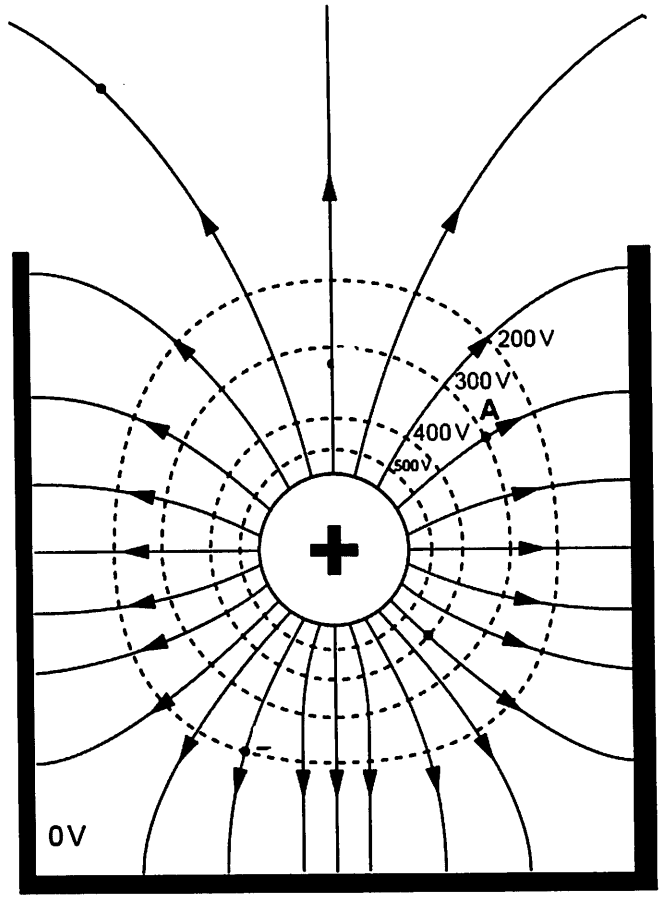

Fig. 4.1 (actual scale)

(i) In order to create the potentials shown in **Fig. 4.1**, the charged circular metal rod was brought into the U-shaped metal frame and the frame was subsequently earthed to 0 V.

With reference to the electric potentials, state and explain if any charges flowed into the U-shaped metal frame upon earthing.

.....

.....

.....

.....

.....[2]

(ii) By taking measurements from the diagram, determine approximate values of the magnitude of the electric field strength at point **A**, giving the unit of electric field strength.

electric field strength = ... [2]

(d) Explain, with the aid of a diagram, how electric and magnetic fields can be used as a velocity selector.

.....

.....

.....

.....

.....

.....

.....[4]

5 The energy bands in a solid are illustrated in **Fig. 5.1**.

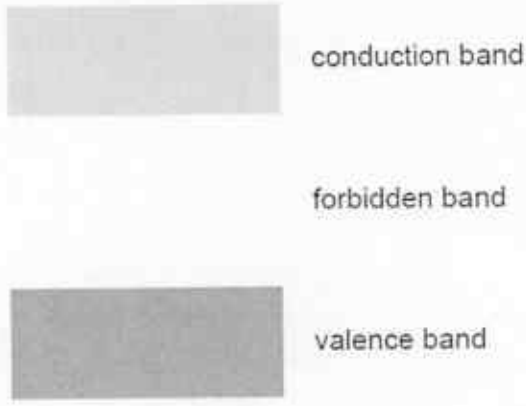

Fig. 5.1

By considering charge carriers and lattice vibrations, use band theory to explain the change of resistance of an intrinsic semiconductor with change of temperature.

.....

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.....

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.....

.....

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.....

.....[6]

Section B

Answer **two** questions from this Section in the spaces provided.

6 **(a)** **(i)** Define *gravitational potential* at a point.

.....

.....[1]

(ii) Explain why values of gravitational potential near to an isolated mass are all negative.

.....

.....

.....[2]

(b) A star **Y** makes an orbit around another stationary star **X** as shown in **Fig. 6.1**. Star **Y** is located about 30,000 light years from the centre of star **X**. The orbital speed of star **Y** is 250 km s^{-1}. Star **X** has a radius of 5.0×10^{22} m.

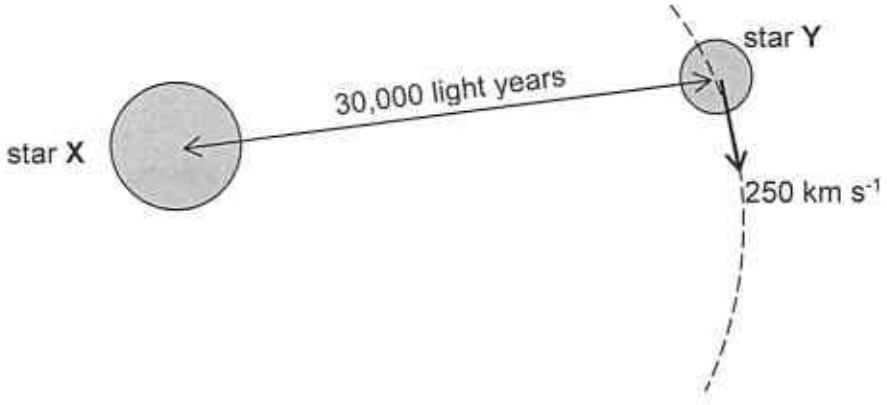

Fig 6.1

(i) Given that 1 light year is the distance travelled by light in a year, show that the radius of star **Y**'s orbit is 2.8×10^{20} m. [1]

(ii) Determine the time taken for one complete revolution taken by star **Y** around star **X**.

time = ... years [3]

(iii) Hence calculate mass of star **X**.

mass = ... kg [2]

(iv) Calculate the initial velocity that an object needs to be projected from star **X**'s surface such that it can drift to infinity without any further propellant. Ignore the gravitational effects of star **Y** and other planets.

velocity = ... $m\ s^{-1}$ [2]

(b) The variation of gravitational potential ϕ due to both the Sun and the Earth with distance is shown in **Fig. 5.2** below.

On the same axes of **Fig. 5.2**, sketch the graph representing the resultant gravitational field strength between them and hence explain how you derived at your answer.

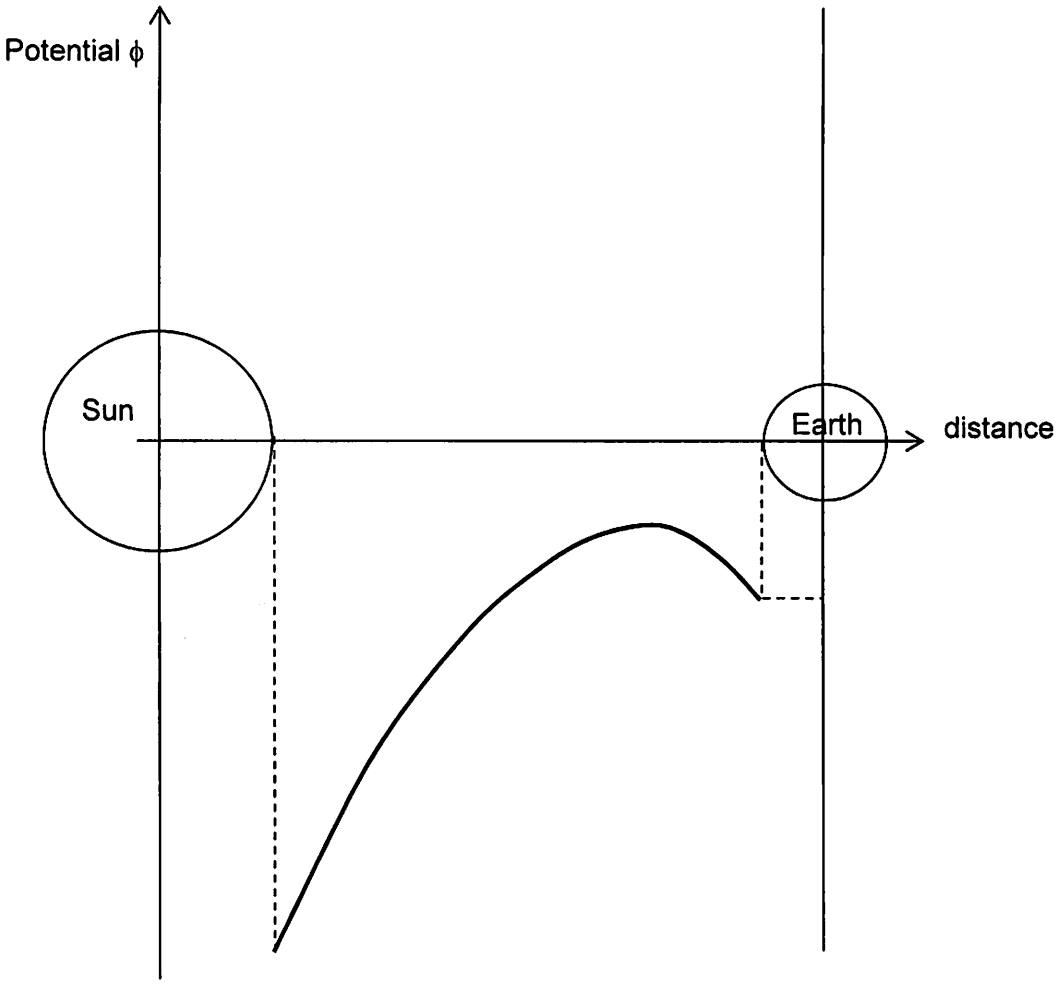

Fig 5.2

.....

.....

.....[3]

(c) Explain if the following statements are valid.

(i) "The gravitational force is significant only when we deal with celestial objects like stars and planets but not with atoms and molecules".

.....

.....

.....[2]

(ii) "Astronauts experience weightlessness in an orbiting spacecraft "

.....

.....

.....[2]

(iii) Some molecules present in the upper layers of the Earth's atmosphere will escape even though the speed required for escape is very much greater than the root mean square speed of the molecules.

.....

.....

.....[2]

7 **(a)** State three conditions for two waves to produce an observable interference pattern.

1. .....

2. .....

3. ..... [2]

(b) The apparatus illustrated in **Fig 7.1** is used to demonstrate two-source interference using light.

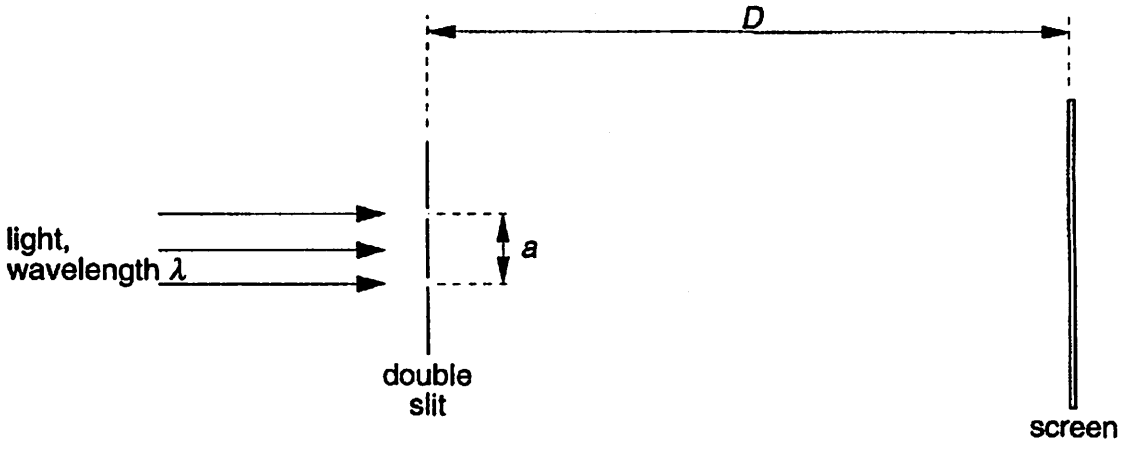

Fig 7.1 (not drawn to scale)

The separation of the two slits in the double slit arrangement is a and the interference fringes are viewed on a screen at a distance D from the double slit. When light of wavelength λ is incident on the double slit, the separation of the bright fringes on the screen is x.

(i) State and explain the effect, if any, on the separation of the fringes and on the contrast between the bright and dark fringes when the following changes are made.

1. The distance D is increased to $2D$, keeping a and λ constant.

Separation: .....

Contrast: .....

.....

.....[2]

2. The incident light is polarised into a single plane before reaching the double slits.

Separation: .....

Contrast: .....

.....

.....[2]

(c) A ripple tank is used to demonstrate the interference pattern between water waves. The wave pattern produced is shown in **Fig 7.2**, where the solid line represents positions of the crests.

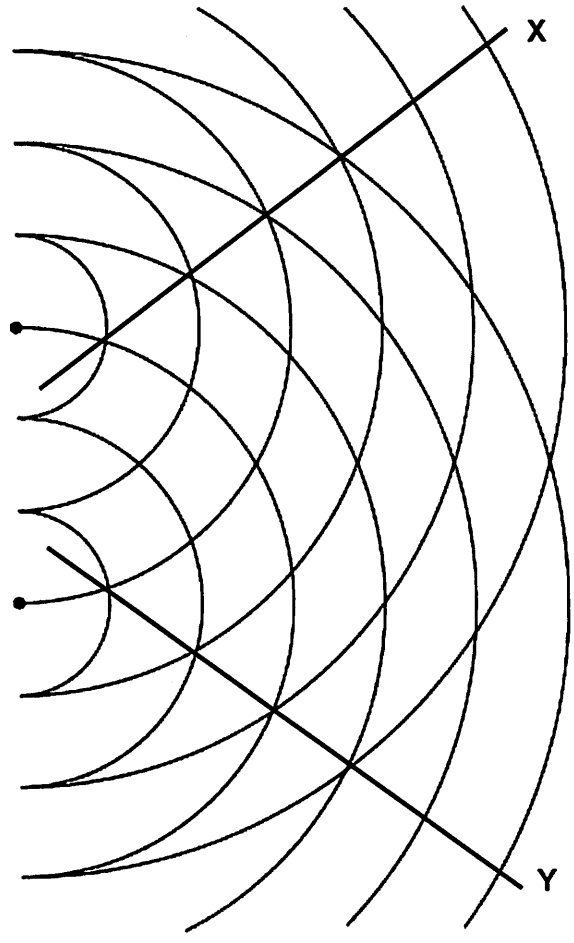

Fig 7.2

Sketch **two** possible lines to show where the minima would be seen between **X** and **Y**. Label these lines as **D**. [2]

(d) A glass tube, closed at one end, has dust sprinkled along its length. A sound source is placed near the open end of the tube, as shown in **Fig 7.3**.

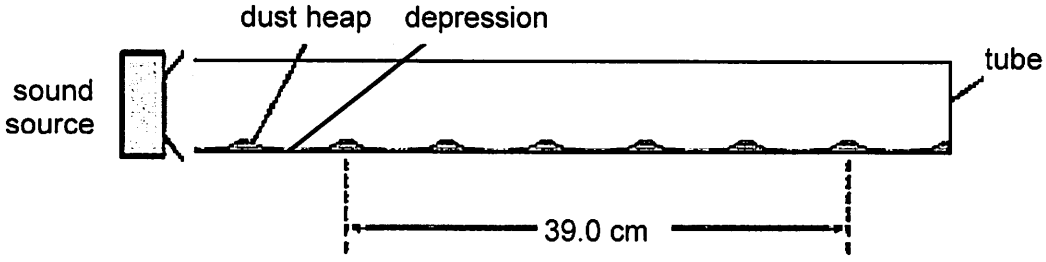

Fig 7.3

The sound emitted by the source is of constant frequency and the dust forms small heaps and depressions in the tube.

(i) Explain, by reference to the properties of stationary waves, why the heaps and depressions are formed.

.....

.....

.....

.....[2]

(ii) The frequency emitted by the source is 2.14 kHz. The distance between six heaps as shown in **Fig 7.3** is 39.0 cm. Calculate the speed of sound in the tube.

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

(iii) The frequency from the sound source is slowly changed until the heaps and depressions disappeared. Explain why.

.....

.....

.....

.....[2]

(e) Visible white light, which has a range for wavelengths of red light of 700 nm to violet light of 400 nm, is passed through a diffraction grating of 200 lines per mm as shown in the **Fig. 7.4**. A screen was placed 3.00 m from the diffraction grating, and is perpendicular to the incident beam of white light.

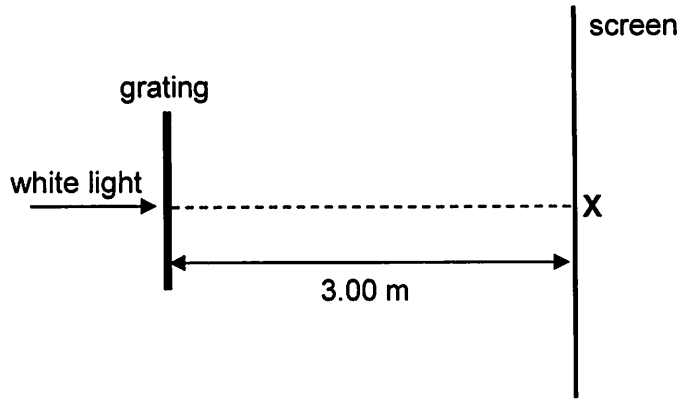

Fig 7.4

(i) State what is observed at point **X** on the screen.

.....[1]

(ii) Determine the range of distances from **X** for the 1st order of fringes observed.

..... m to ..... m [2]

(iii) Show with calculation whether the 3rd order fringes overlaps with the 2nd order fringes.

.....

.....[2]

8 **(a)** Describe the alpha particle scattering experiment and explain its importance in determining the structure of atoms.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....[5]

(b) In a fission process, a neutron collides with a uranium-235 nucleus and causes a nuclear reaction summarised by the following equation.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{54}Xe + {}^{97}_{38}Sr + 2\,{}^{1}_{0}n$$

The binding energy per nucleon of each nucleus is as follows:

$^{235}_{92}U$	1.216×10^{-12} J
$^{137}_{54}Xe$	1.344×10^{-12} J
$^{97}_{38}Sr$	1.378×10^{-12} J

(i) Explain how chain reaction may be possible in this process.

..... [1]

(ii) Energy produced in the reaction is released as kinetic energy of the fission products. Show that the energy released of the fission products is 200 MeV.

[2]

(iii) The energy released of the fission products is converted to 3065 MW of thermal power in a nuclear plant. Calculate the number of fission processes taking place each second in the plant.

number of fission processes = ... [2]

(iv) Since the Earth was formed, the value of the atomic abundance ratio of uranium-235 has gradually decreased.

Abundance ratio of uranium-235 = $\frac{Number\ of\ atoms\ of\ uranium-235}{Total\ number\ of\ atoms\ of\ uranium}$

Nowadays, the atomic abundance ratio of uranium-235 is 0.00718.

Explain why a nuclear fission chain reaction, could not, nowadays, take place in naturally occurring uranium on Earth.

.....

.....

..... [2]

(c) Samples of Moon rock were collected by some astronauts. Scientists measure the relative abundance of strontium isotopes in samples of Moon rock to determine the age of the rocks.

(i) Define the term *isotope*.

..... [1]

(ii) The isotope of rubidium Rb-87, found in the Moon rock is radioactive. It decays by beta emission to form strontium Sr-87. Sr-87 has an atomic number of 38 and is stable.
Write the nuclide decay equation representing this decay. [2]

(iii) Explain how it is possible for an electron to be emitted in beta decay.

.....

..... [1]

(iv) The decay constant of rubidium Rb-87 is 1.44×10^{-11} yr^{-1}.
Calculate, in years, the half-life of rubidium Rb-87.

half-life = ... yr [1]

(v) The Moon rocks are formed about 4.0×10^{9} years ago. The rate at which strontium Sr-87 atoms are created is equal to the rate of decay of the rubidium Rb-87 atoms.

Using information given in **(c)(iv)**, show that this rate has remained almost constant over the age of the rock. [3]

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SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME			
CG		**INDEX NO.**	

PHYSICS **9646/01**

Preliminary Examination **22nd Sept 2016**
Paper 1 Multiple Choice **1 hour 15 minutes**

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 **forty** 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	/ 40

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm\omega\sqrt{x_0^2 - x^2}$

mean kinetic energy of a molecule $E = \frac{3}{2}kT$

of an ideal gas

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = Q/ 4 \pi \varepsilon_0 r$

alternating current/ voltage, $x = x_0 \sin \omega t$

transmission coefficient, $T \alpha \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions

1 A quantity R is found using the following expression

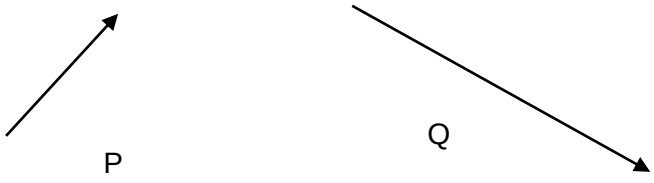
$$P = \frac{1}{8}Q - 2R$$

where $P = 0.70 \pm 0.03$
$Q = 25.0 \pm 0.5$

What is the value of R, together with its uncertainty?

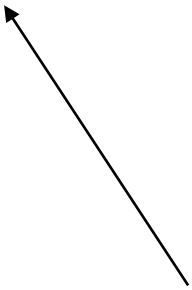
A 1.21 ± 0.02
B 1.21 ± 0.05
C 1.213 ± 0.05
D 1.2 ± 0.5

2 Vectors P and Q are drawn to scale.



Which diagram represents the vector (P – Q)?

A



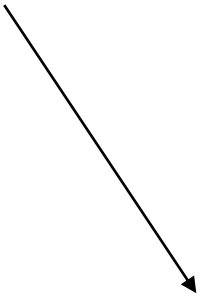
B



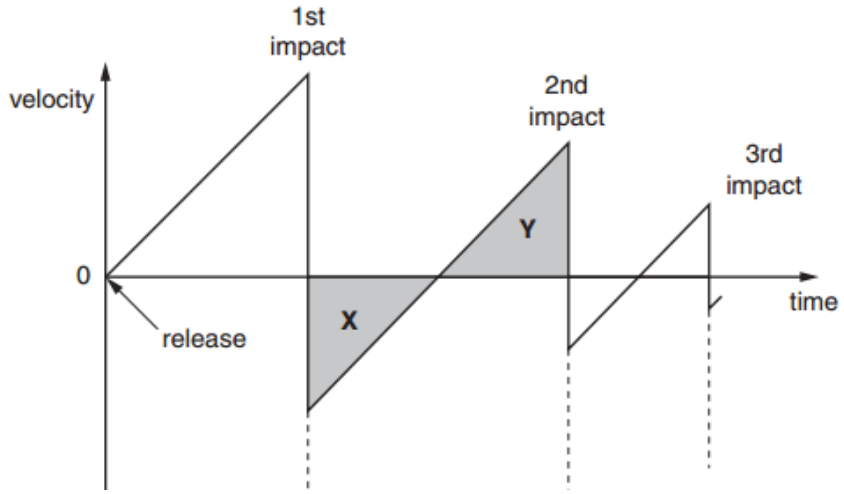
C



D



3 A ball is released from rest above a horizontal surface. The graph shows the variation with time of its velocity.

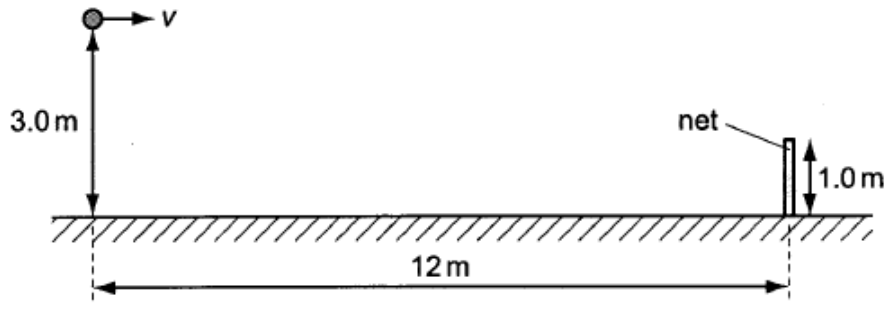


Areas **X** and **Y** are equal.

This is because

A the ball's acceleration is the same during its upward and downward motion.
B the speed at which the ball leaves the surface after an impact is equal to the speed at which it returns to the surface for the next impact.
C for one impact, the speed at which the ball hits the surface equals the speed at which it leaves the surface.
D the ball rises and falls through the same distance between impacts.

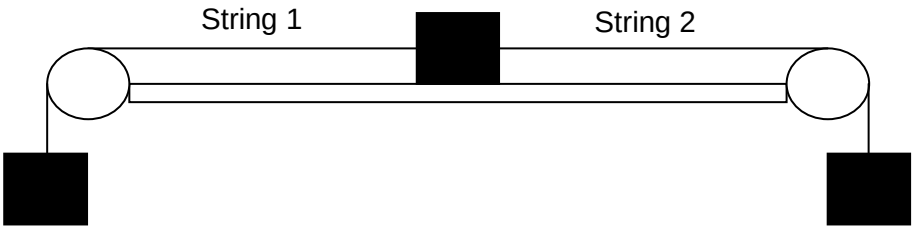
4 A tennis ball is hit horizontally with speed v from a height of 3.0 m such that it just clears a net which is 1.0 m high. The ball is at a horizontal distance of 12.0 m from the net initially.



What is the value of v? Neglect the effects of air resistance.

A 16 m s^{-1} **B** 19 m s^{-1} **C** 30 m s^{-1} **D** 38 m s^{-1}

5 Three identical blocks are connected by two strings through frictionless pulleys, as shown below. The middle block rests on a smooth table.



What is the ratio of $\frac{\text{tension in String 2 after String 1 was cut}}{\text{tension in String 2 before String 1 was cut}}$?

A 0.25 **B** 0.5 **C** 1 **D** 2

6 A cart X, moving along a horizontal frictionless track, collides with a stationary cart Y. The two carts become attached and move off together.

Which statement about this interaction is correct?

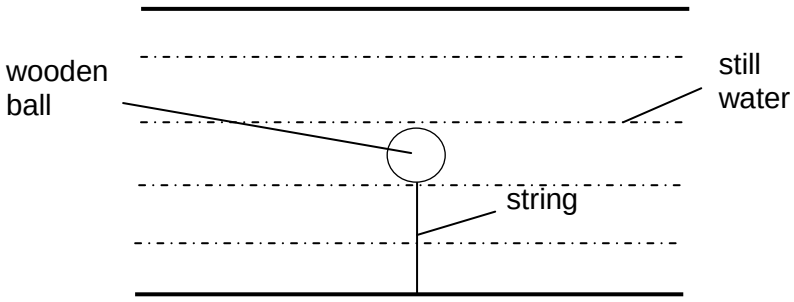
A Cart X loses some of its momentum as heat in the collision.

B Cart X shares its momentum with Cart Y but some of its kinetic energy is lost.

C Some of the momentum of trolley X is changed to kinetic energy in the collision.

D Some of the kinetic energy of trolley X is changed to momentum in the collision.

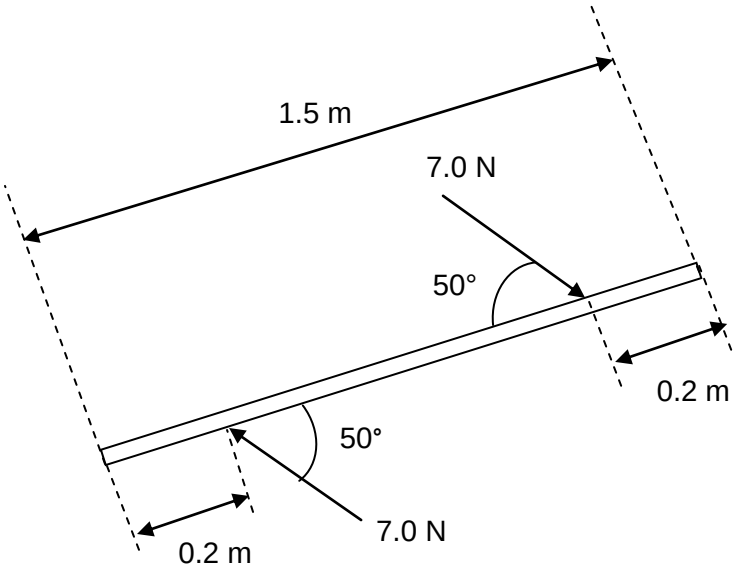
7 A wooden ball of density 800 kg m^{-3} and volume 1.0 m^3 is fastened to the bottom of a freshwater pond. The density of freshwater is 1000 kg m^{-3}.



If the string suddenly breaks, what is the initial acceleration of the ball?

A 0.25 m s^{-2} **B** 1.25 m s^{-2} **C** 2.50 m s^{-2} **D** 12.50 m s^{-2}

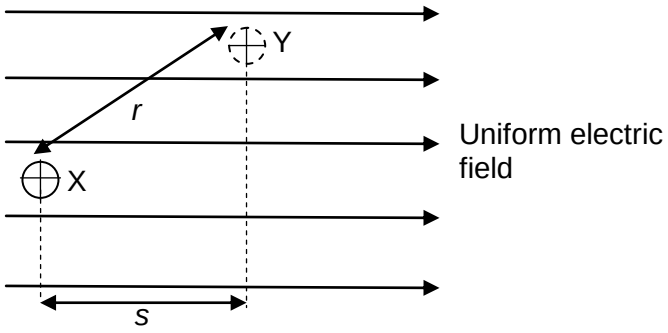
8 Two 7.0 N forces act on a beam of length 1.5 m. The forces are parallel and act in opposite directions at a distance of 0.2 m from each end of the beam. The angle between the forces and the beam is 50°.



What is the torque of the couple exerted on the beam?

A 4.95 Nm **B** 5.90 Nm **C** 6.75 Nm **D** 8.04 Nm

9 A positive ion is placed at point X in a uniform electric field. Due to the electric field, it experienced an electric force *F* and it is moved from point X to point Y.



What is the change in the electric potential energy of the ion?

A decreases by *Fs*

B increases by *Fs*

C decreases by *Fr*

D increases by *Fr*

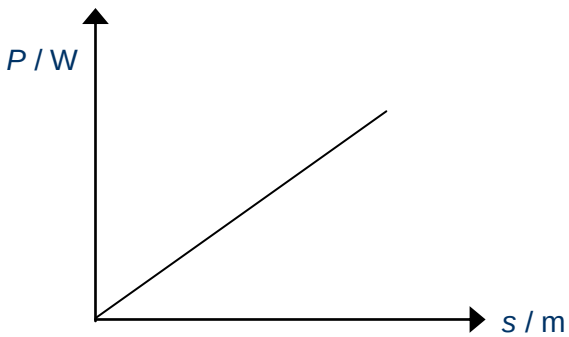
10 A car starts from rest and its driving force causes its speed to increase at a constant rate.

Which graph shows the variation of the power output of the vehicle P with the distance travelled by the car s?

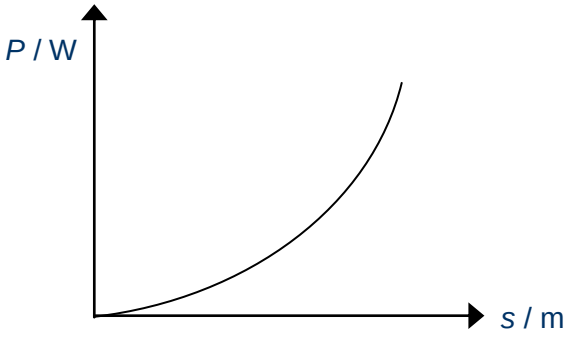
A



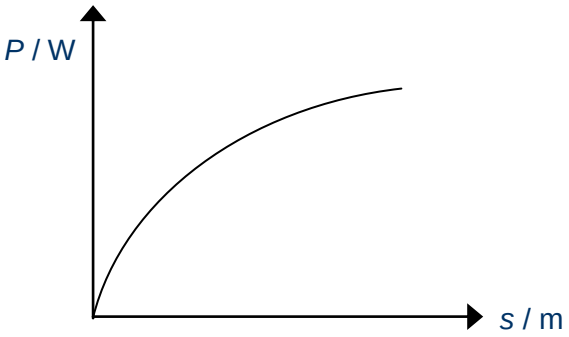
B



C



D

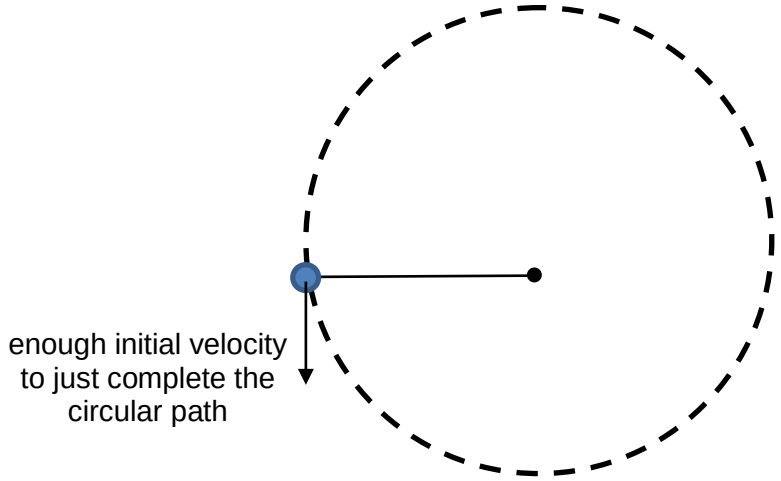


11 An object undergoing uniform circular motion with radius r rotates by an angle of θ in time t.

What are the magnitudes of linear velocity and acceleration?

	linear velocity	acceleration
A	$\frac{\theta r}{t}$	$\frac{\theta^2 r}{t^2}$
B	$\frac{2\pi r}{t}$	$\frac{4\pi^2 r}{t^2}$
C	$\frac{2\pi r}{t}$	$\frac{\theta^2 r}{t^2}$
D	$\frac{\theta r}{t}$	$\frac{4\pi^2 r}{t^2}$

12 An object of mass of *m* is tied to a string and projected with enough initial velocity such that it is just able to complete a vertical circular path.



What is the maximum tension the string experiences throughout the circular path?

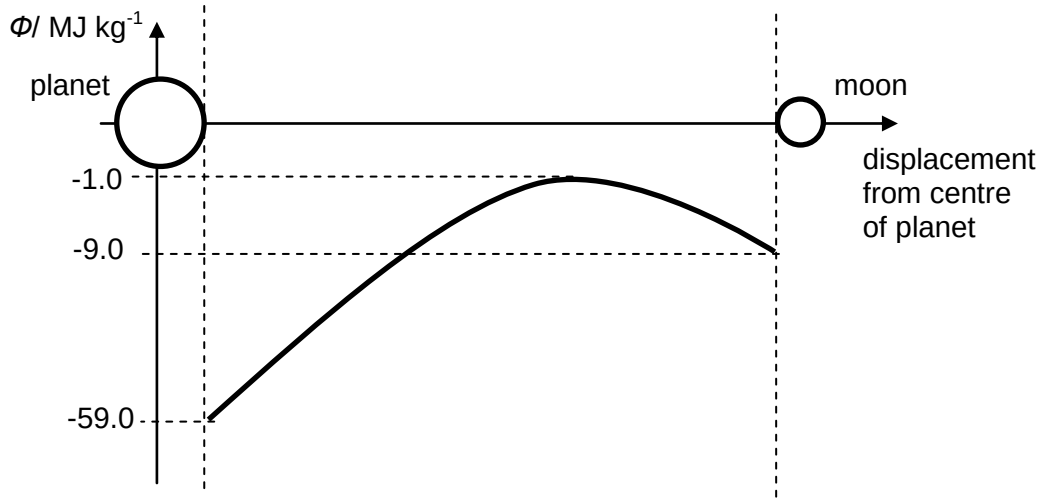
A 2*mg* **B** 3*mg* **C** 5*mg* **D** 6*mg*

13 It is known that the acceleration of free fall measured at the poles would be different from that which is measured at the Equator.

How does the measurement at the poles differ from that at the Equator? The Earth is assumed to be a sphere with radius 6400 km.

A Measurement at poles is 0.0338 m s^{-2} more than measurement at Equator.
B Measurement at poles is 0.0338 m s^{-2} less than measurement at Equator.
C Measurement at poles is 254 x 10^{-9} m s^{-2} more than measurement at Equator.
D Measurement at poles is 254 x 10^{-9} m s^{-2} less than measurement at Equator.

14 The figure below shows the variation of gravitational potential Φ between a planet and its moon.

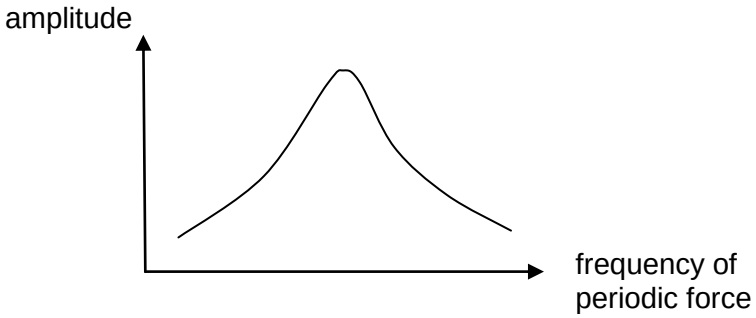


An object of 2 kg is projected from the moon's surface towards the planet's surface.

What is the minimum kinetic energy that the object will have when it hits the planet's surface?

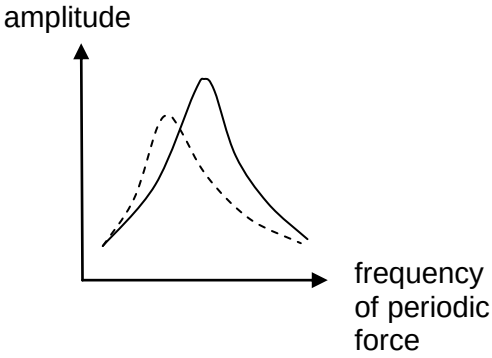
A 8.0 MJ **B** 16.0 MJ **C** 100.0 MJ **D** 116.0 MJ

15 An external periodic force is applied on a spring-mass oscillating system to cause forced oscillation. The frequency of the external periodic force is varied to obtain the corresponding amplitude of oscillation and the results are as shown (solid line) in the diagram below.

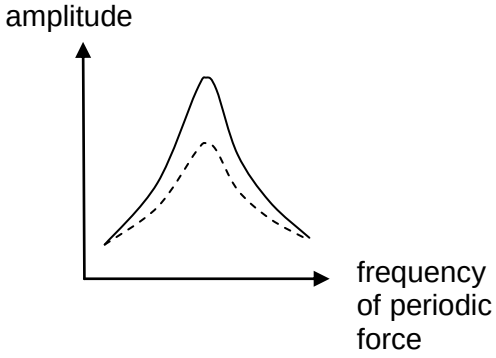


Which of the following graphs (dotted line) shows the correct variation of amplitude with frequency when only the mass of the oscillating system is increased?

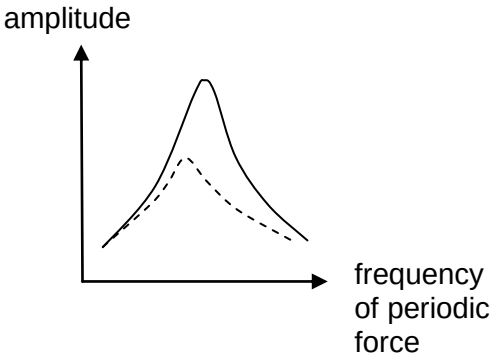
A



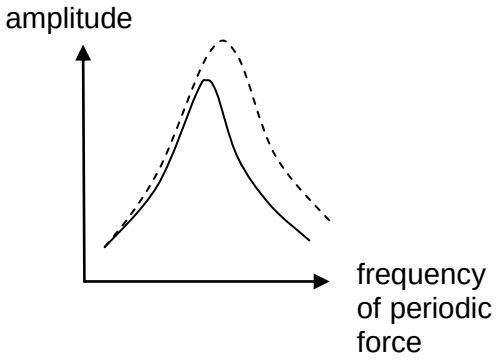
B



C



D



16 A mass attached to a spring is undergoing simple harmonic oscillations vertically. Interchange between kinetic energy (KE), gravitational potential energy (GPE) and elastic potential energy (EPE) takes place.

Which of the following is a correct description of these energies as the mass moved from the highest point to lowest point of oscillation?

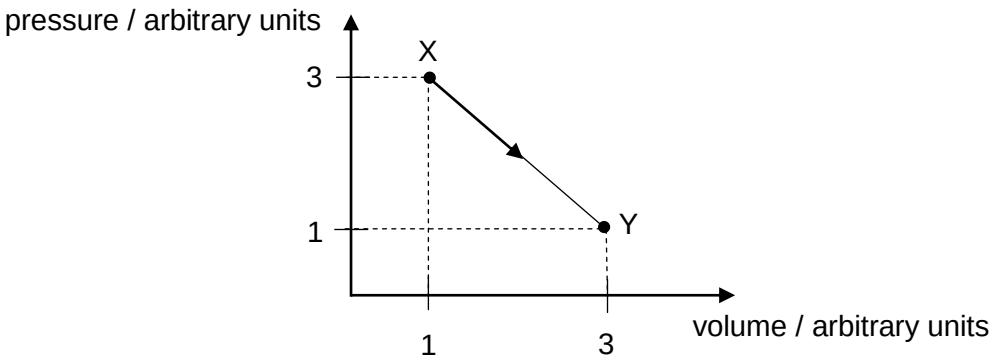
A GPE decreased linearly and was converted to EPE. Hence EPE also varies linearly.

B EPE and GPE decreases non-linearly to zero at equilibrium position and hence KE is maximum at equilibrium.

C Since KE varies non-linearly and GPE varies linearly, EPE must vary non-linearly.

D At equilibrium position, half of the GPE lost will always be converted to EPE and the other half will always be converted to KE.

17 A fixed amount of ideal gas undergoes a process XY as shown,



Which of the following statements is true of the process XY?

A There is zero heat supplied to gas.
B There is positive heat supplied to gas.
C There is an increase in internal energy of gas.
D There is a decrease in the internal energy of gas.

18 Which of the following statements regarding specific latent heat of fusion l_f and vaporisation l_v in general is true?

A l_f is higher than l_v because more energy is required to break the strong bonds of a solid during melting than for breaking the bonds in a liquid during vaporisation.

B l_f is higher than l_v because less energy is required during the vaporisation as some of the molecules of the liquid already have enough energy to break free from the liquid even below the boiling point.

C l_v is higher than l_f because more energy is required during the vaporisation as a significant amount of energy is required to do work against the atmosphere.

D l_v is higher than l_f because vaporisation occurs at a higher temperature than fusion.

19 The energy carried by a wave is proportional to

A the square of the wave's amplitude as well as the square of intensity.

B the square of the wave's amplitude as well as the intensity.

C the wave's amplitude as well as the square of intensity.

D the wave's amplitude as well as the intensity.

20 A point source of sound radiates energy uniformly in all directions. The amplitude of oscillation of the air molecules at a distance of 3.2 m from the source is 64 μm. Assuming that the sound is propagated without energy loss, what is the distance from the source when the amplitude of the oscillation of the air molecules is 8 μm?

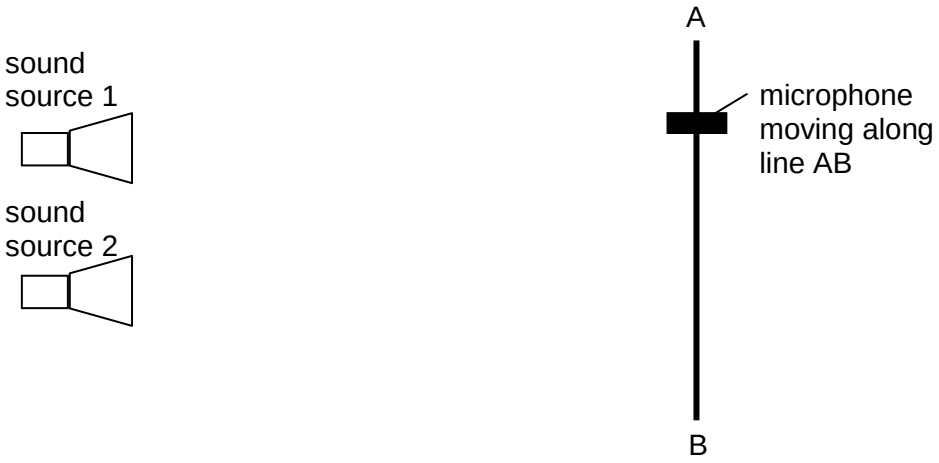
A 26 m **B** 82 m **C** 205 m **D** 655 m

21 Monochromatic light of wavelength 600 nm is incident normally on a diffraction grating. The grating has 500 lines per mm.

What is the angle between the two second-order diffracted beam?

A 17.5^0 **B** 35^0 **C** 37^0 **D** 74^0

22 A student set up a two-source interference experiment with sound sources positioned as shown below. However, there was no observable interference pattern when a microphone is moved along line AB.



Which of the following could be a likely cause for the lack of observable interference pattern?

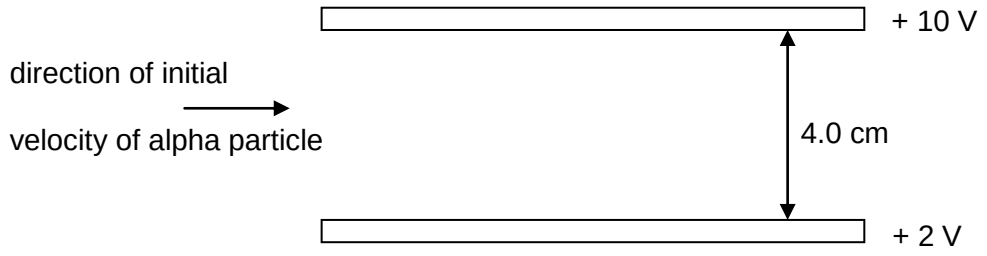
A The distance from sound sources to detector is not much larger than the spacing between the sources.

B The intensities of sound from the two sources are not approximately the same.

C The sound sources are coherent but not in phase.

D Waves from the sound sources always meet antiphase along line AB.

23 An alpha particle is projected into a region between two parallel positively charged plates with a velocity parallel to the plates, as shown in the diagram below.



Upon exiting the region between the plates, it deflects vertically by 1.0 cm.

What is the change in kinetic energy of the particle?

A 1.6×10^{-19} J **B** 3.2×10^{-19} J **C** 6.4×10^{-19} J D 12.8×10^{-19} J

24 Which of the properties of objects below best accounts for the force due to each field?

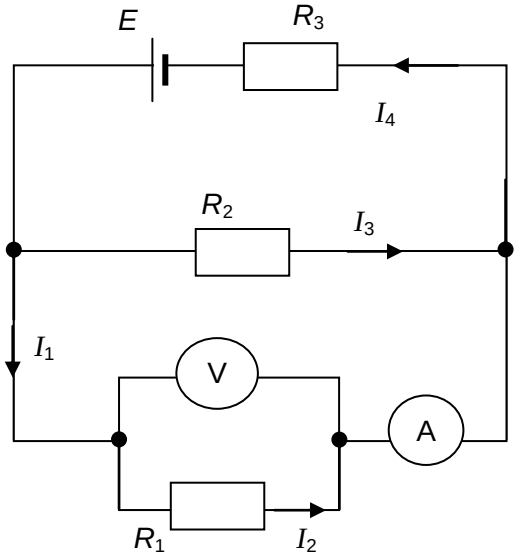
	Field	Property
A	Gravitational	mass
	Electric field	moving charge
	Magnetic field	magnetic poles
B	Gravitational	weight
	Electric field	charge
	Magnetic field	magnetic poles
C	Gravitational	mass
	Electric field	positive charge
	Magnetic field	moving charge
D	Gravitational	mass
	Electric field	stationary charge
	Magnetic field	magnetic poles and moving charge

25 The potential difference between point X and point Y in a circuit is 20 V. Within 15 s, the energy of the charge carriers changes by 12 J.

What is the current betweeen X and Y?

A 0.040 A **B** 0.11 A **C** 9.0 A **D** 25 A

26 The figure below shows a circuit that comprises of a battery, 3 resistors, a voltmeter and an ammeter. The e.m.f. of the battery is *E*.



Which of the following shows the correct expression for the voltmeter reading and ammeter reading?

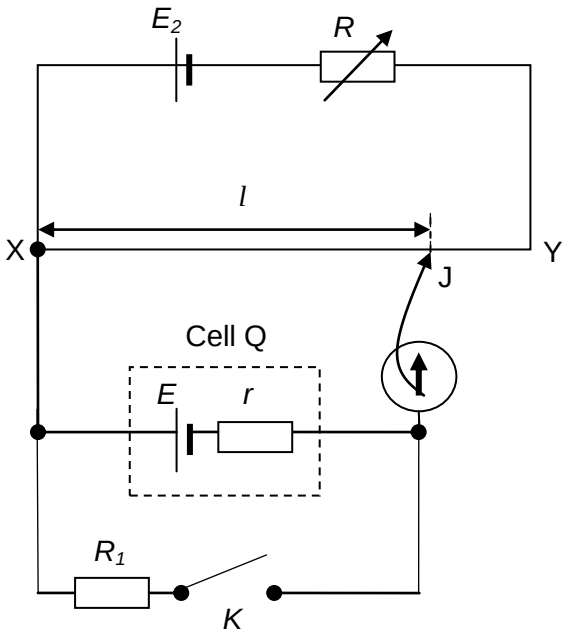
	Ammeter reading / A	Voltmeter reading / V
A	I_2	$I_4R_3 + I_3R_2$
B	$I_3 + I_4$	E
C	I_1	$E - I_4R_3$
D	$I_1 + I_3$	I_2R_1

27 When a 4 Ω resistor is connected between the terminals of a certain cell, a 2 A current flows through the circuit. When the 4 Ω resistor is replaced by a 2 Ω resistor, the current changes to 3 A.

Which of the following show the correct values of the e.m.f. and the internal resistance of the cell?

	e.m.f / V	internal resistance / Ω
A	15	4
B	12	2
C	10	1
D	8	zero

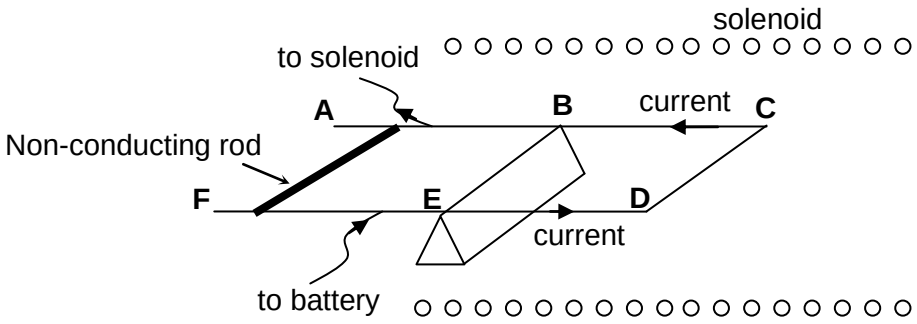
28 In order to determine the value of e.m.f of cell Q, the following circuit is set up. XY is a wire with uniform resistance. When switch K is open, the balance length is l.



Which of the following statements is false?

A Placing another resistor in series with cell Q will change the value of l.
B Increasing the value of the variable resistance R will increase the the value of l.
C When switch K is closed, the value of l will decrease.
D The value of the r is not required for the determination of E.

29 A current balance device was set up to determine the magnetic field strength created by a solenoid as shown below. The first experiment determined the magnetic field strength as *B*.

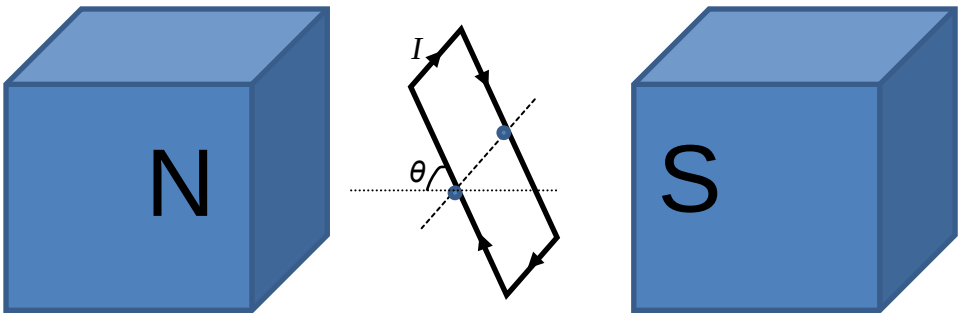


The setup was used again with one or some of the factors changed. A non-conducting rod of a larger mass had to be used in the second experiment.

Which one of the following could most likely be the changes made?

A Another frame with a shorter length for CD was used.
B The current passing through the solenoid and the number of turns of the solenoid are reduced.
C The first experiment was set up such that the direction of the Earth's magnetic field is opposite to the magnetic field created by the coil while the second experiment had both magnetic fields in the same direction.
D The knife edge was moved closer to CD.

30 A rectangular coil with *N* turns is placed in a uniform horizontal magnetic field *B* which makes an angle θ with the plane of the coil as shown below. The coil carries a current I and has an area *A*.



What is the torque of the couple experienced by the coil?

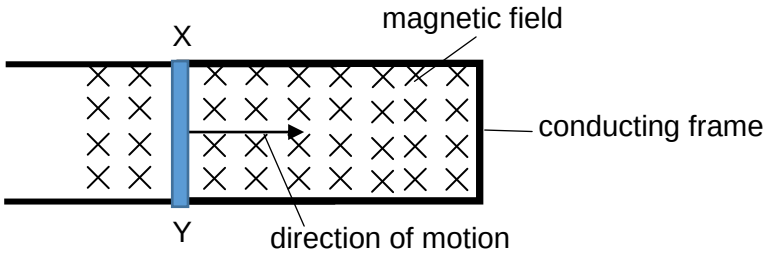
A $NBAI\cos\theta$

B $2NBAI\cos\theta$

C $NBAI\sin\theta$

D $2NBAI\sin\theta$

31 The diagram below shows a wire conductor, XY, positioned perpendicular to a uniform magnetic field directed into the paper moving across a conducting frame.



Which of the following statements describes the relative potentials between X and Y and the direction of induced current in the conducting frame?

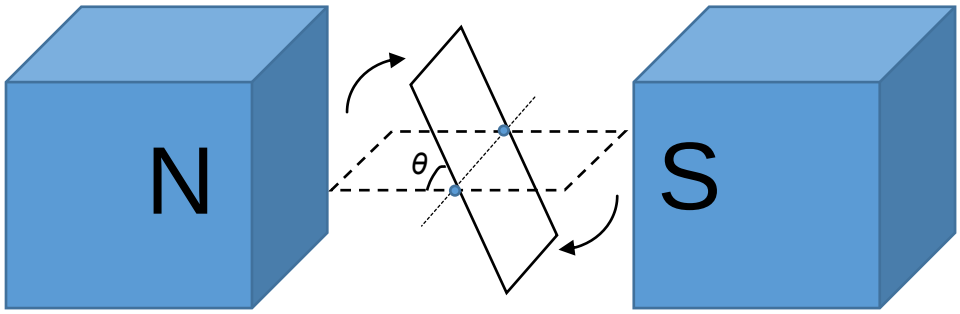
A Potential at X is higher than potential at Y, so current flows in the clockwise direction through the conducting frame.

B Potential at X is higher than potential at Y so current flows in the anticlockwise direction through the conducting frame.

C Potential at Y is higher than potential at X, so current flows in the clockwise direction through the conducting frame.

D Potential at Y is higher than potential at X, so current flows in the anticlockwise direction through the conducting frame.

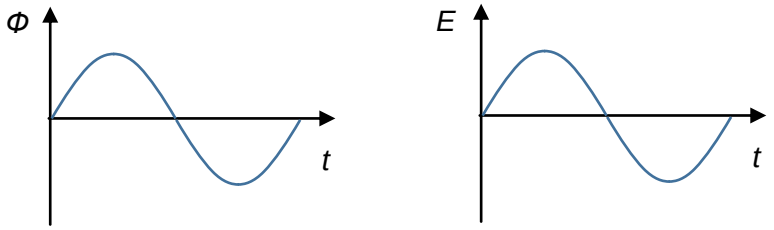
32 A rectangular coil is rotated in a magnetic field as shown.



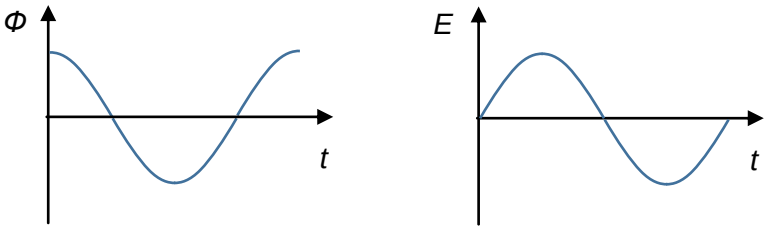
At time $t = 0$, angle $\theta = 0°$.

Which of the following options show the correct variation of flux Φ and induced e.m.f E with t for one full rotation?

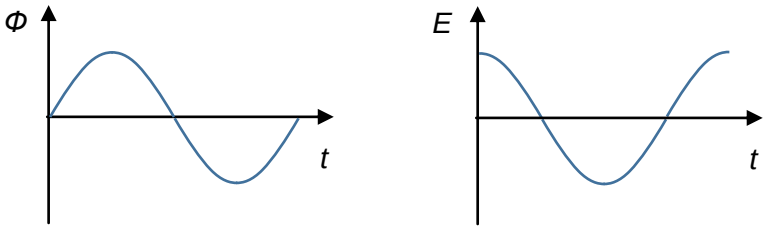
A



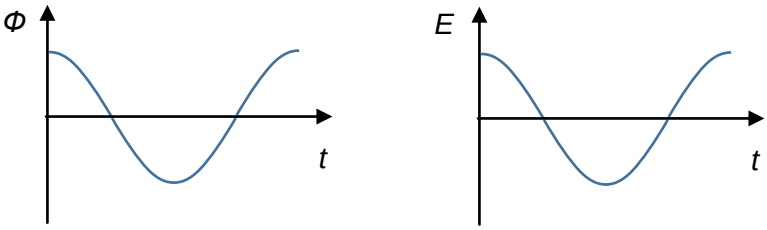
B



C



D



33 As seen in Fig. (a), 4 diodes are placed in a circuit with a resistor *R* and alternating current (AC) source that changes the direction of current after each cycle. The positions of the 4 diodes are represented by the dotted boxes.

When a CRO is placed across the resistor R to observe the variations of the current. The graph in Fig. (b) is obtained.

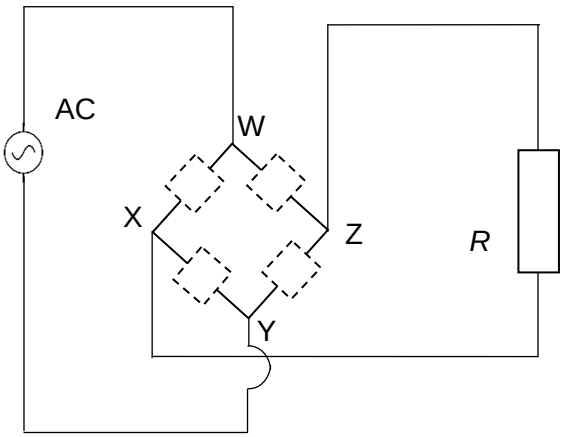


Fig. (a)

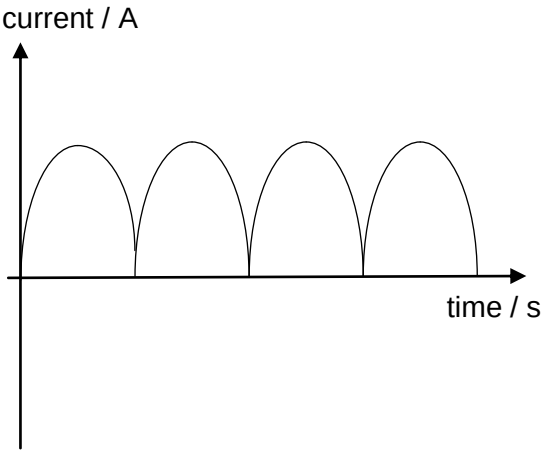
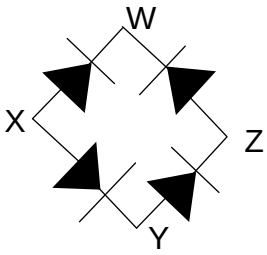


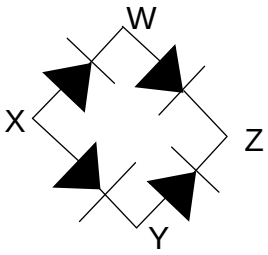
Fig. (b)

Which of the following shows the correct placement of the diodes?

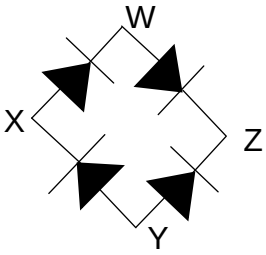
A



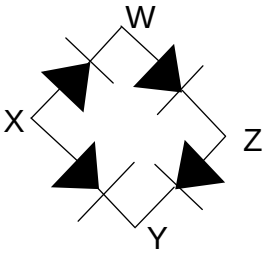
B



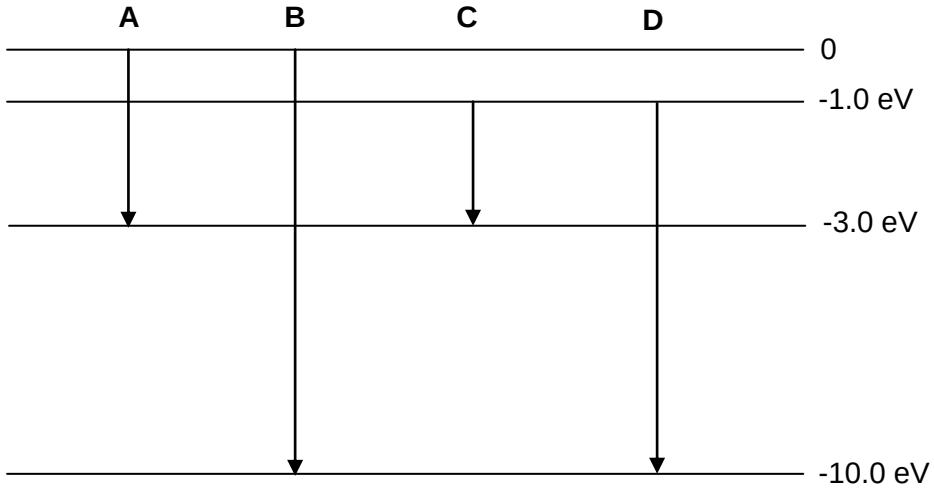
C



D



34 The energy levels of an atom of an element are shown in the following diagram. Which energy transitions will produce photons of wavelength 620 nm?



35 An electron is moving at 10^{-4} times that of the speed of light. What is the region of the electromagnetic spectrum of its wavelength?

A Microwave
B X-ray
C Visible light
D Radio waves

36 A particle is defined by position (x, y, z) and corresponding momenta (p_x, p_y, p_z). According to Heisenberg's Uncertainty principle, which of the following observables cannot be measured simultaneously?

A x and p_y **B** y and p_y, **C** p_y and p_z **D** x and z

37 Which of the following statements regarding "Quantum Tunnelling" of electrons is false?

A When the width of the potential barrier decreases, the reflection coefficient decreases.

B When the height of the potential barrier increases, the transmission coefficient decreases.

C The energy of the electron which has successfully tunnelled across a potential barrier is less than the energy it has before the barrier.

D The amplitude of the wave function across the barrier is lower than the amplitude of the wave function before the barrier.

38 Which of the following statements concerning a laser system is true?

A An external energy source is needed to create a metastable state so that population inversion can occur.

B A laser beam is monochromatic because there is a fixed energy gap between the meta-stable state of the electrons and the lower electron energy level.

C A laser beam achieves its brightness because of the two fully reflecting mirrors placed at the ends of the tube containing the lasing substance.

D A laser beam is coherent and of a single wavelength because of spontaneous emission.

39 For an alpha scattering experiment, which of the following statements is correct?

A As alpha particles passes through gold foil they diffract and land on different positions on the screen, leading to regions of maxima and minima.

B Alpha particles slow down when it hits the gold foil thus giving out X-ray photons.

C Most particles passed through undeflected because of barrier tunnelling.

D Back scattering coupled with most particles passing through undeflected suggest an atom model with concentrated small nucleus.

40 A sample of radioactive nuclide X with nucleon number 239 and half-life T decays by emission of an alpha particle to form daughter nuclide Y. The original sample is placed on a weighing machine and gave a reading of 478 g.

What is the reading after a time of $3T$?

A 60 g **B** 411 g **C** 418 g **D** 471 g

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME

CG **INDEX NO.**

PHYSICS 9646/02

Preliminary Examination **14th Sept 2016**
Paper 2 Structured Questions **1 hour 45 minutes**

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	/ 4
Q2	/ 12
Q3	/ 6
Q4	/ 6
Q5	/ 6
Q6	/ 3
Q7	/ 8
Q8	/ 15
Q9	/ 12
Total marks	/ 72

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_0^2 - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q/ 4 \pi \varepsilon_0 r$
alternating current/ voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	α	$\exp(-2kd)$
where	k	=	$\sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions

1 Two parallel strings S_1 and S_2 are attached to a disc of diameter 12 cm, as shown in Fig. 1.1.

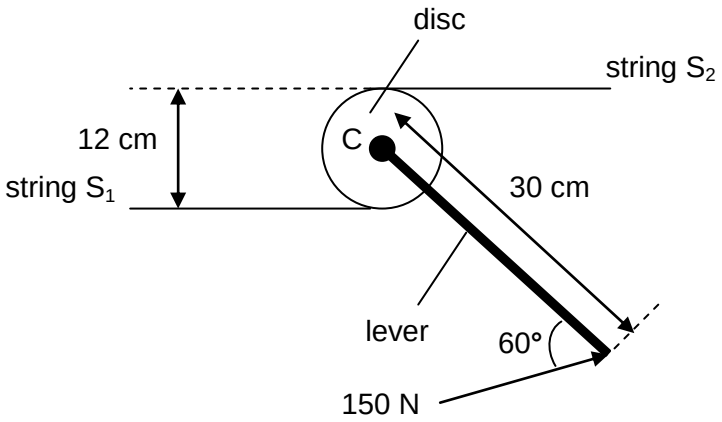


Fig. 1.1

The disc is free to rotate about an axis normal to its plane. The axis passes through the centre C of the disc.

A light lever of length 30 cm is attached to the disc. When a force of 150 N is applied on the lever at an angle of 60° at its end, equal forces are produced in S_1 and S_2. The disc remains in equilibrium.

Determine

(a) the moment of the 150 N force about the centre of the disc,

moment = …… N m [1]

(b) the force in S_1. Explain your working.

force = …… N [3]

2 **(a)** To determine the specific heat capacity of a liquid, the apparatus is set up as shown in Fig. 2.1. An electric heater contains a tube through which the liquid flows at a constant rate. The liquid in the tube passes over a heating coil, as shown in Fig. 2.1.

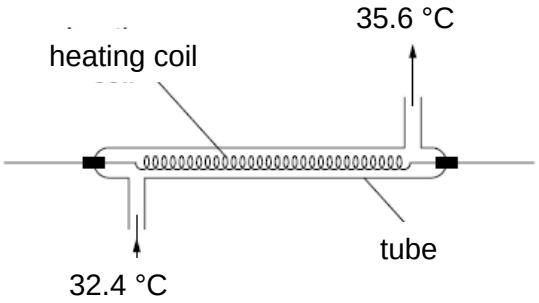


Fig. 2.1

For a particular experiment to determine the specific heat capacity of the liquid, the power supplied to the heating coil *P* is varied for different mass flow rate *m* of the liquid. The temperature of the liquid flowing into the tube is maintained at 32.4 °C and the temperature of the liquid flowing out of the tube is 35.6 °C.

The variation with *m* of *P* is shown in Fig. 2.2.

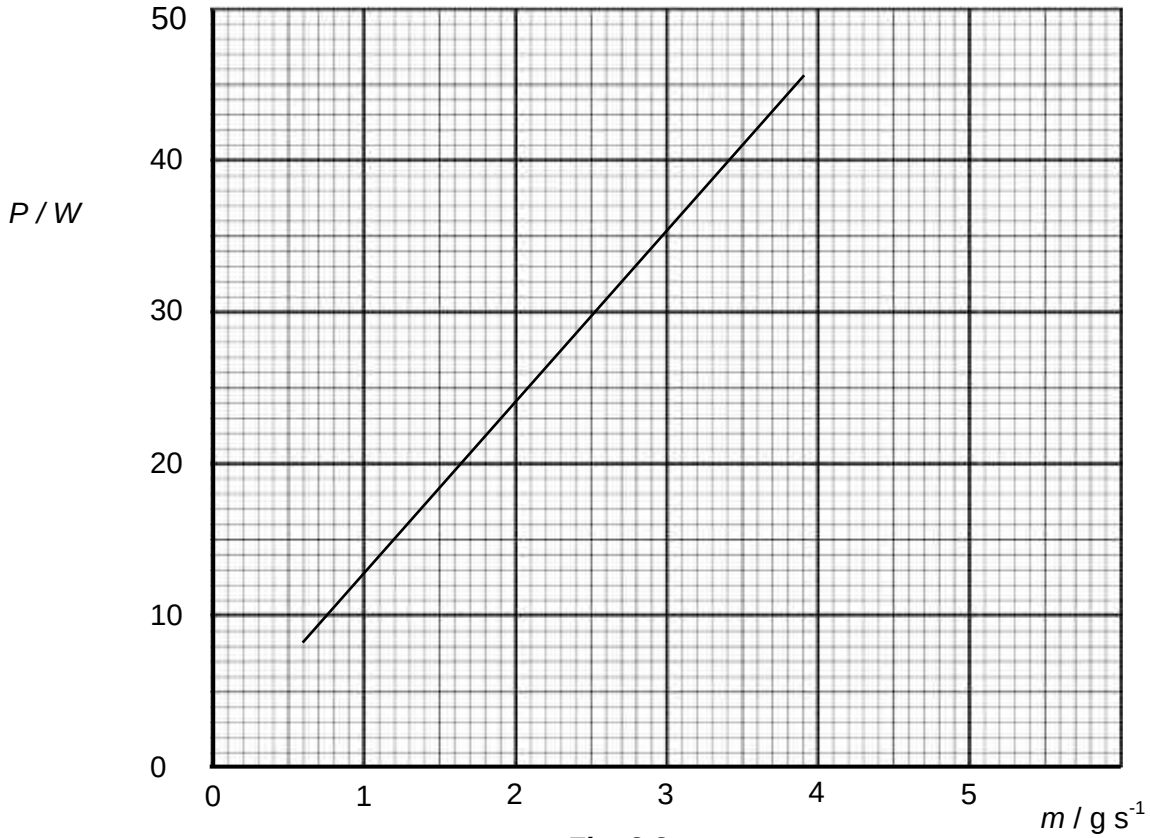


Fig. 2.2

(i) State the significance of the y-intercept.

…… [1]

(ii) Use Fig. 2.2 to determine the value for the specific heat capacity in J g^{-1} °C^{-1} of the liquid. Show your working.

specific heat capacity = …….. J g^{-1} °C^{-1} [3]

(b) An unknown substance boils at a temperature of 120°C. The volume of 1.00 kg of element in the liquid state at 120°C is 1.10 x 10^{-3} m^3. The volume of 1.00 kg of the element in gaseous state at 120°C and atmospheric pressure 1.01 x 10^5 Pa is 2.00 m^3.

When 1.00 kg of the substance in liquid state becomes gas at 120 °C under atmospheric pressure,

(i) determine the work done against the atmosphere

work done against atmosphere = …… J [2]

(ii) determine the increase in internal energy of this mass of element during vaporisation. The specific latent heat of vaporisation of the substance at 120°C is 4.36 x 10^6 J kg^{-1}.

increase in internal energy = …… J [2]

(c) A fixed amount of gas is sealed in a container with a piston as shown in Fig. 2.3.

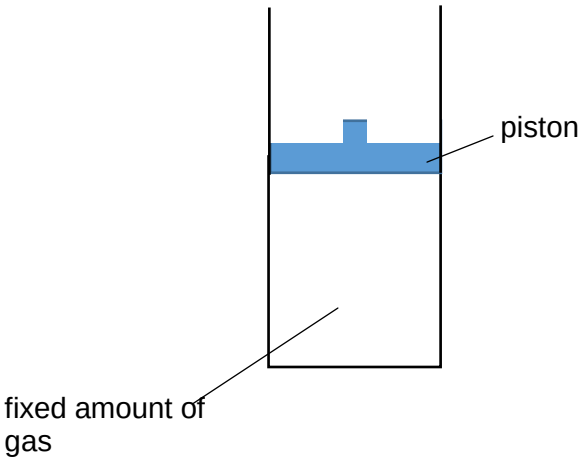


Fig. 2.3

When the gas is heated,

(i) with the piston fixed in position, explain microscopically why the pressure of the gas will increase.

……

……

……

…… [2]

(ii) with the piston free to move, explain microscopically why the temperature of the gas may remain constant.

……

……

……

…… [2]

3 Two charged metal spheres A and B, of similar sizes are isolated in space, as shown in Fig. 3.1. Sphere A is positively charged while sphere B is negatively charged. Magnitude of charge on sphere A is larger than magnitude of charge on sphere B

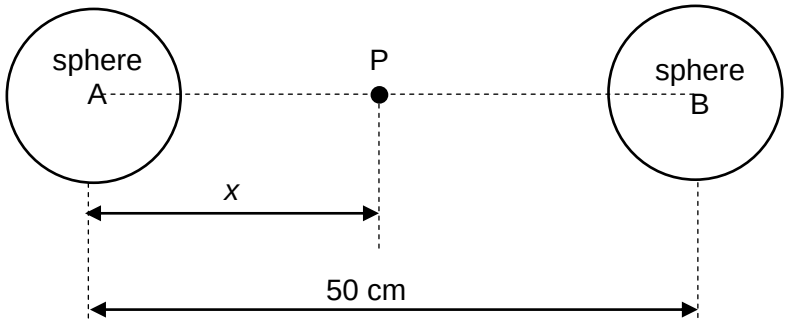


Fig. 3.1

The centres of the spheres are separated by a distance of 50 cm. Point P is at a distance *x* from the centre of the sphere A along the line joining the centres of the two spheres.

(i) Sketch the variation with *x* of the electric field strength *E* at P on Fig. 3.2 for *x* = 0 cm to *x* = 50 cm. [3]

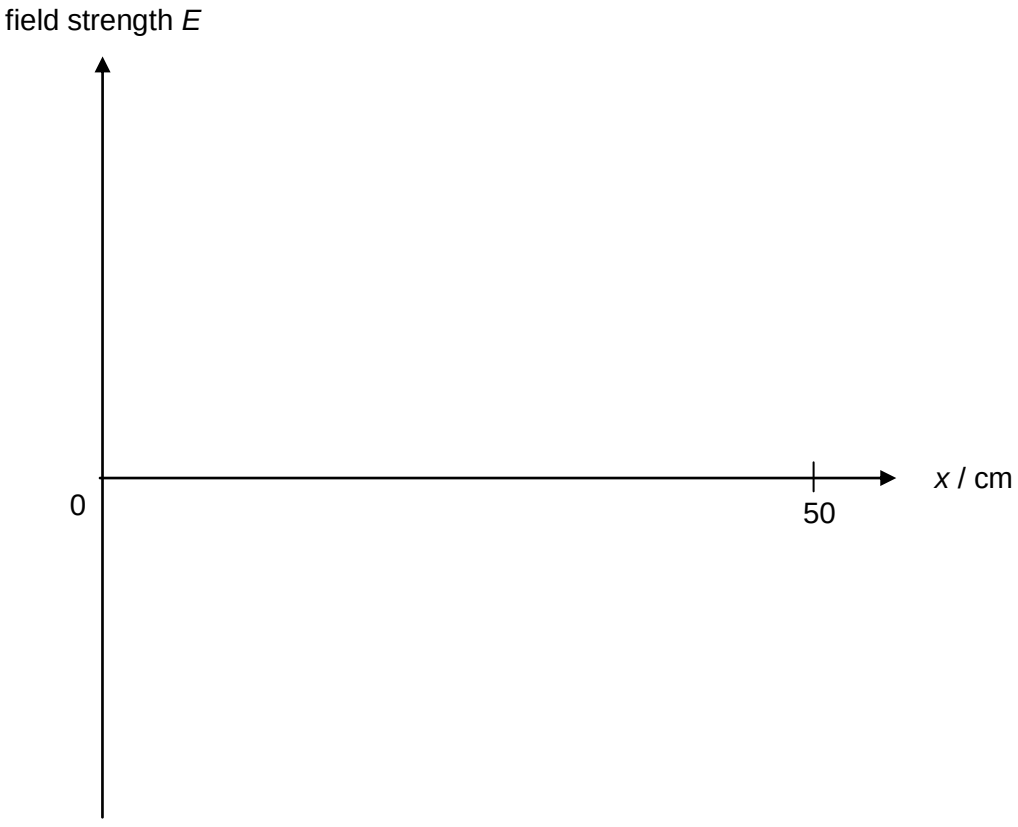


Fig. 3.2

(ii) Magnitude of charge on sphere A is 3 times that of sphere B. Determine the value of x for which point P has zero resultant electric potential.

x = …… m [2]

(iii) State whether the point where resultant electric potential is zero must coincide with the point of minimum resultant field strength.

……[1]

4 A solenoid, with insulated copper wire, has current flowing in the wire as shown in Fig. 4.1.

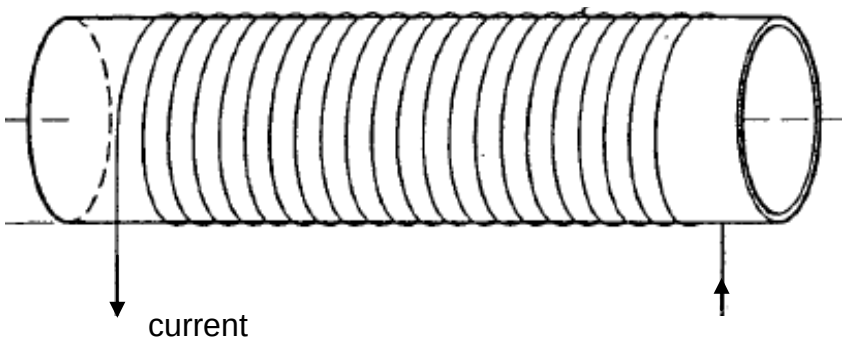


Fig. 4.1

(a) On Fig. 4.1, draw the magnetic flux pattern within and around the solenoid. [2]

(b) The solenoid is in a vacuum. An electron is injected into the magnetic field of the solenoid with a speed 3.0 x 10^6 m s^{-1} at an angle of 40° to the axis of the solenoid as shown in Fig. 4.2.

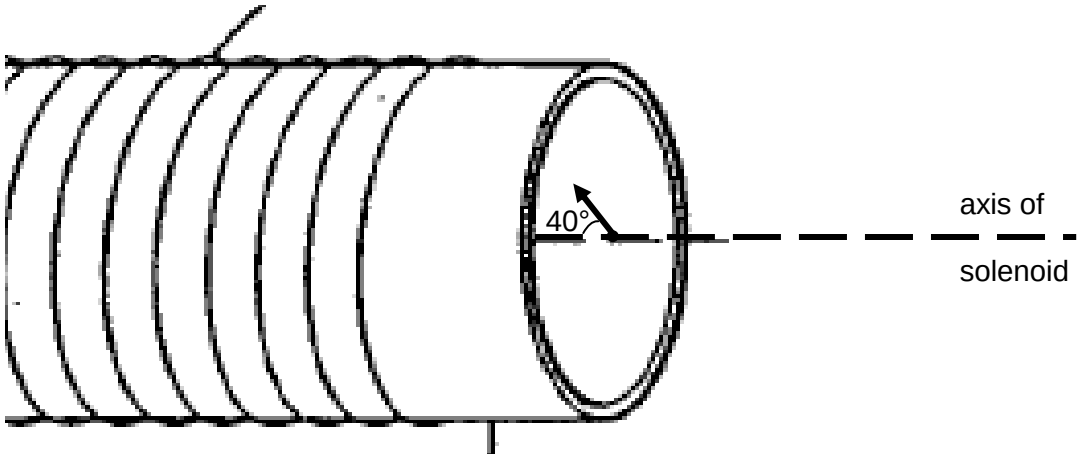


Fig. 4.2

(i) Determine the electromagnetic force acting on the electron given that the magnetic flux density of the solenoid is 2.0 mT.

electromagnetic force = ……..… N [2]

(ii) By considering the components of the velocity parallel to the magnetic field and at right-angles to the magnetic field, describe and explain the path of the electron in the field.

...……

…...……

……...……

……...…… [2]

5 **(a)** Some data for the variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface are shown in Fig. 5.1.

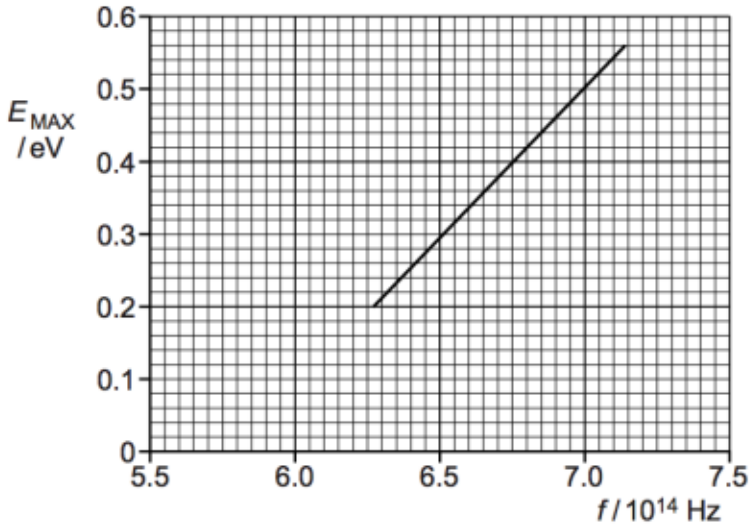


Fig. 5.1

Use Fig. 5.1 to determine

(i) the threshold frequency,

threshold frequency = ... Hz [1]

(ii) the work function energy, in eV, of the metal surface.

work function energy = ... eV [2]

(b) 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. 5.2.

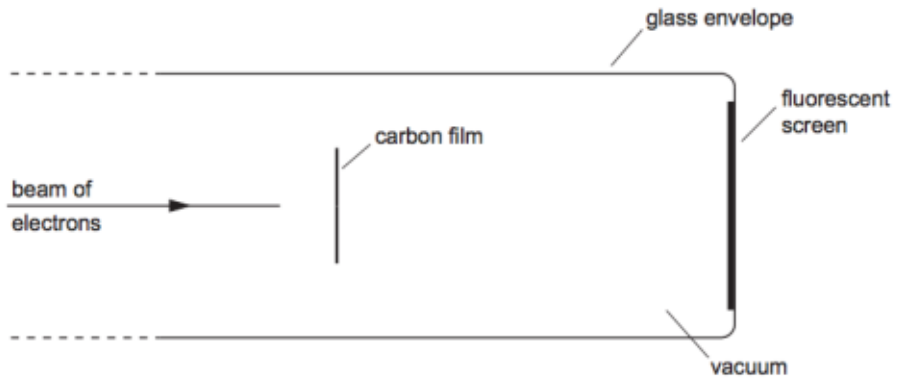


Fig. 5.2

(i) Describe briefly the pattern that is actually observed on the screen.

…….…….…….…….. [1]

(ii) The speed of the electrons is gradually increased.

State and explain what change, if any, is observed in the pattern on the screen.

…….…….…….……

…….…….…….……

…….…….…….. [2]

6 Explain how does a p-n junction act as a rectifier when it is placed in a forward bias connection.

……

……

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……

……

……

……

……

…….…… [3]

7 **(a)** A 5.0 g sample of isotope of Bismuth-212, $^{212}_{83}Bi$, has a half-life of 60.5 min and decays to form Thallium-208. The rest mass of Bismuth-212 is 211.9913*u*.

(i) Determine the activity of radioactive Bismuth-212 after 3.5 hrs.

activity = …….. Bq [3]

(ii) Determine the total number of Thallium-208 which is formed by the decay of Bismuth-212 within the 3.5 hours.

number of Thallium-208 formed = …… [2]

(iii) Suggest why the actual number of Thallium-208 detected after 3.5 hours was less than the calculated answer in **(ii)**.

……

……[1]

(b) A cloud chamber enclosing air saturated with alcohol vapour is used to make visible the path of ionising radiation. When ionising radiation passes through this vapour, it causes ionisation and vapour condenses to form a 'vapour trail'. A radioactive source emitting alpha and beta particles are placed in the cloud chamber. The paths of the alpha and beta particles are traced in, as shown in Fig. 7.1

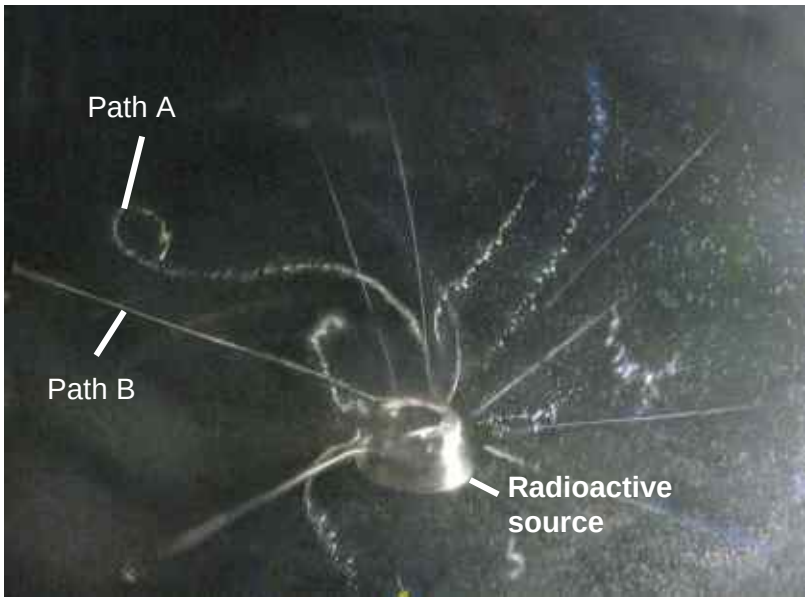

Fig. 7.1

State the type of particle that form path A and B and explain the shape of the paths.

……

……

…… [2]

8 Ultrasonic sound waves (ultrasound) have frequencies outside the audible range of the human ear, that is, greater than about 20 kHz.

As ultrasound passes through a medium, wave energy is absorbed. The rate at which energy is absorbed by unit mass of the medium is known as *dose-rate*. The dose-rate is measured in W kg^{-1}. The total energy absorbed by unit mass of the medium is known as the *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. 8.1 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}.

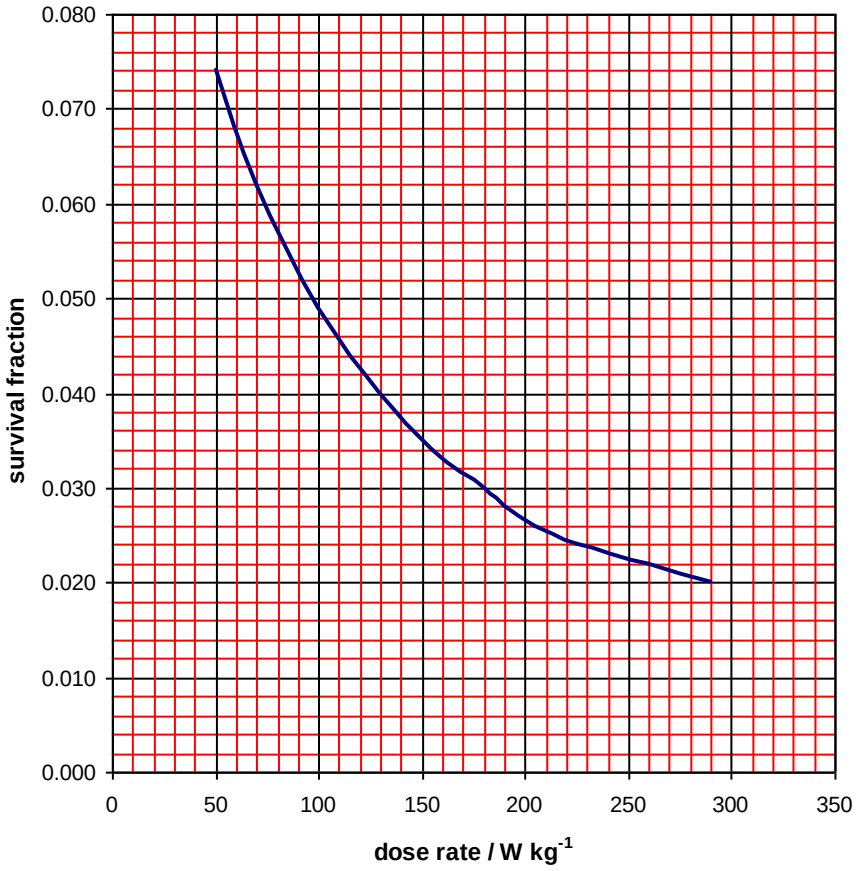

Fig. 8.1

(a) **(i)** Read off from Fig. 8.1 the survival fraction for a dose rate of 200 W kg^{-1}.

SF = ... [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]

(b) Survival fraction depends not only on dose-rate but also on absorbed dose. Fig. 8.2 shows the variation with dose rate of $\log_{10}(SF)$ for different values of absorbed dose.

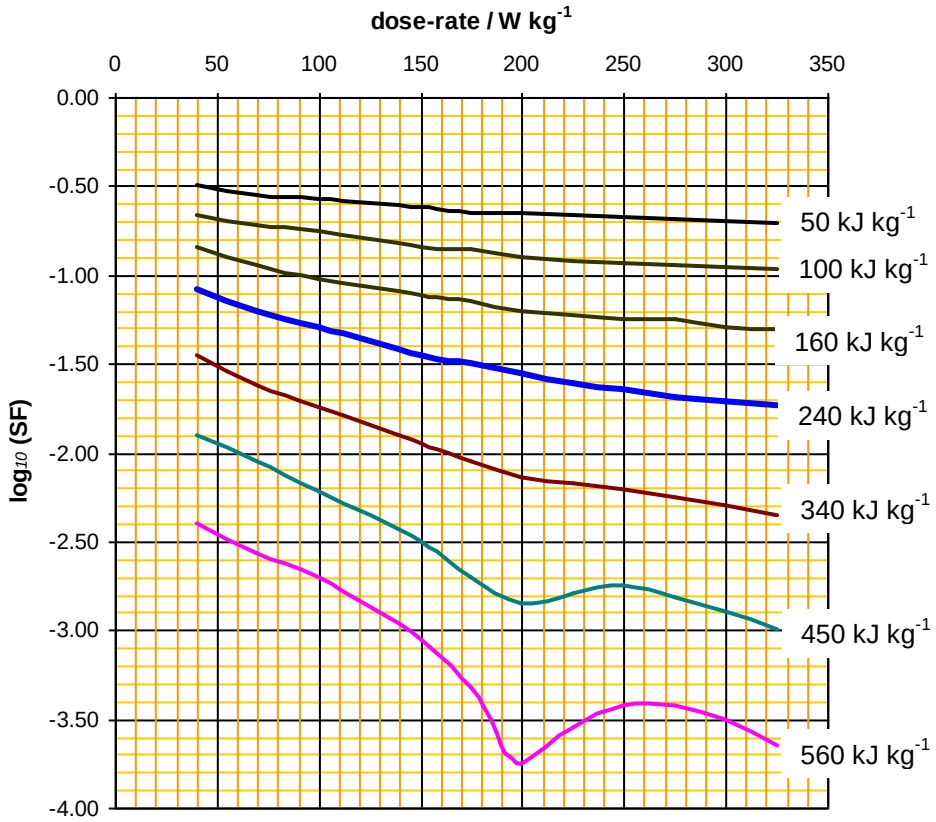

Fig. 8.2

(i) Identify the line in Fig. 8.2 that corresponds to the data given in Fig. 8.1. Label this line ***L***. [1]

(ii) By reference to Fig. 8.2, complete the table of Fig. 8.3 for a dose-rate of 200 W kg^{-1}. [1]

***Absorbed dose* / kJ kg^{-1}**	**$\log_{10}$ (*SF*)**
50	-0.65
100	-0.90
160	-1.20
240	-1.55
340	-2.13
450	
560	

Fig. 8.3

(c) Use your values in table of Fig. 8.3 to plot, on the axes of Fig. 8.4**,** a graph to show variation with absorbed dose of $\log_{10}(SF)$ for dose rate of 200 W kg^{-1}. [3]

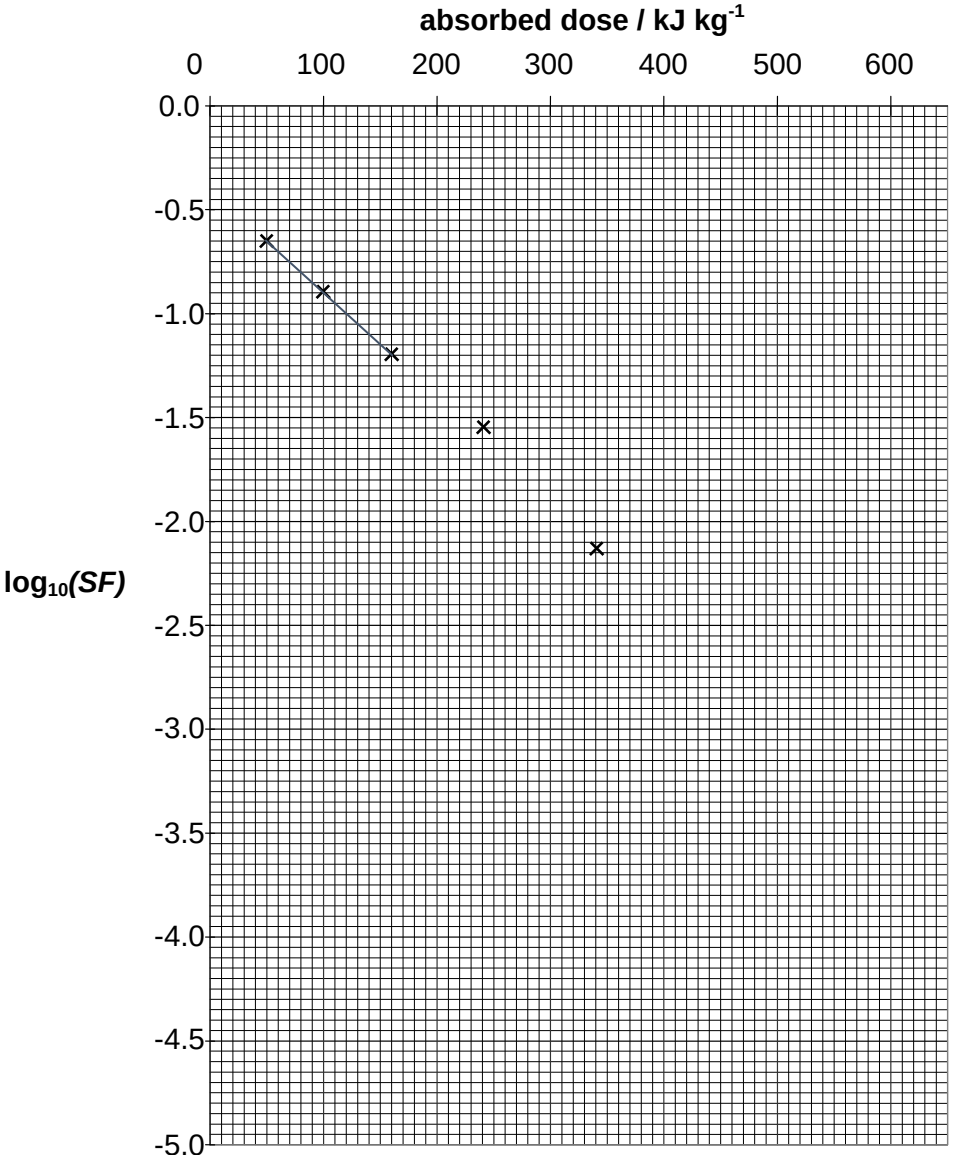

Fig. 8.4

(d) 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 that is provided for this theory by

(i) Fig. 8.2,

……

……

…… [1]

(ii) Fig. 8.4.

……

……

…… [2]

(e) The theory outlined in **(d)** suggests that the resultant survival fraction $(SF)_R$ due to the 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) Give the corresponding expression of $\log_{10}(SF)_R$ in terms of $\log_{10}(SF)_1$ and $\log_{10}(SF)_2$. You may wish to use an equation of the form $\log_{10}(ab) = \log_{10}(a) + \log_{10}(b)$. [1]

(ii) State how the graph of Fig. 8.4 may be used to determine $(SF)_R$ for an absorbed dose of 560 kJ kg^{-1}.

……

……

…… [1]

(iii) Discuss whether it is possible, by reference to your graph of Fig. 8.4**,** to determine separate values of $(SF)_1$ and $(SF)_2$ for the absorbed dose of 560 kJ kg^{-1}.

……

……

…… [2]

9 A fine wire mesh has individual wires that are spaced very close together. See Fig. 9.1.

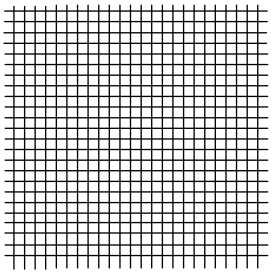

Fig. 9.1

The mesh behaves like two diffraction gratings placed at right angles to each other.

The spacing between the wires of the mesh is to be determined accurately. Design a laboratory experiment to determine the spacing between the wires using light sources of different wavelengths which are known.

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

(a) the type of light source to be used, giving a reason for your choice,
(b) the procedure to be followed and the measurements that would be taken,
(c) how the spacing between the wires would be deduced,
(d) any important precautions you would take to improve accuracy of your experiment,
(e) any safety precautions you may take.

Diagram

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PHYSICS 9646/03

Preliminary Examination **19th Sept 2016**
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 **A**
Answer **all** questions.

Section **B**
Answer any **two** 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	/ 9
Q2	/ 5
Q3	/ 5
Q4	/ 5
Q5	/ 5
Q6	/ 5
Q7	/ 6
Q8	/ 20
Q9	/ 20
Q10	/ 20
Total marks	/ 80

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm\omega\sqrt{x_0^2 - x^2}$

mean kinetic energy of a molecule $E = \frac{3}{2}kT$

of an ideal gas

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = Q/4\pi\varepsilon_0 r$

alternating current/ voltage, $x = x_0 \sin \omega t$

transmission coefficient, $T \alpha \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided

1 A ball falls off a building that is (70 ± 1) m high. It takes 3.78 s to hit the ground. It is estimated that there is a percentage uncertainty of ± 8% in measuring this time interval.

(a) Determine the acceleration of free fall of the ball to an appropriate number of significant figures.

acceleration = …….… ± …….. m s^{-2} [4]

(b) The variation with time *t* of the velocity *v* of another ball falling through air is shown in Fig. 1.1.

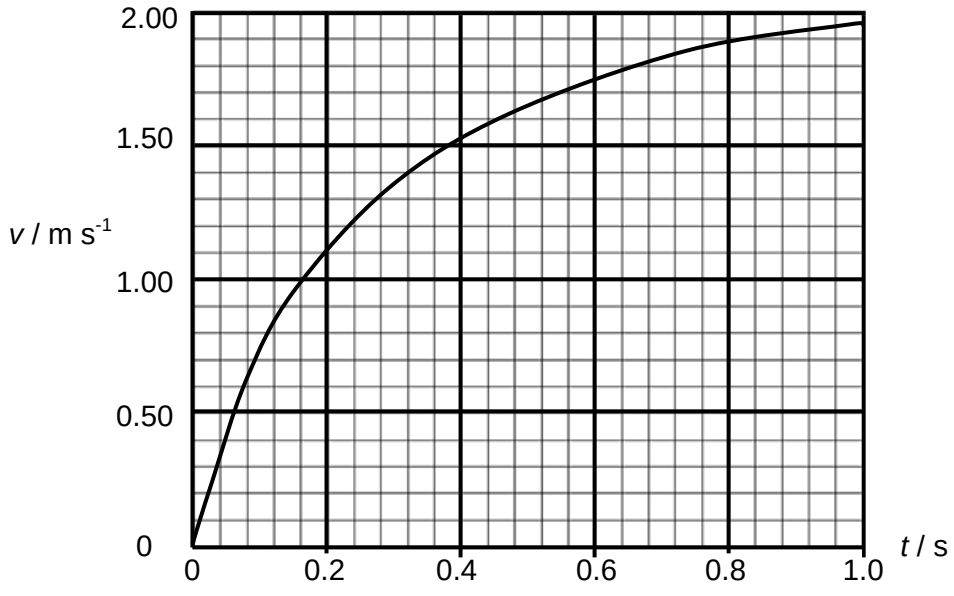

Fig. 1.1

(i) Using Fig. 1.1, describe how the speed of the ball varies with time.

……..……..……

……..……..…….. [1]

(ii) Determine the acceleration of the ball falling through air at time t = 0.4 s.

acceleration = ... m s^{-2} [2]

(iii) The mass of the ball is 25 g. Determine the resistive force acting on the ball at time t = 0.4 s.

resistive force = ... N [2]

2 Coherent light is incident normally on a double slit, as shown in Fig. 2.1.

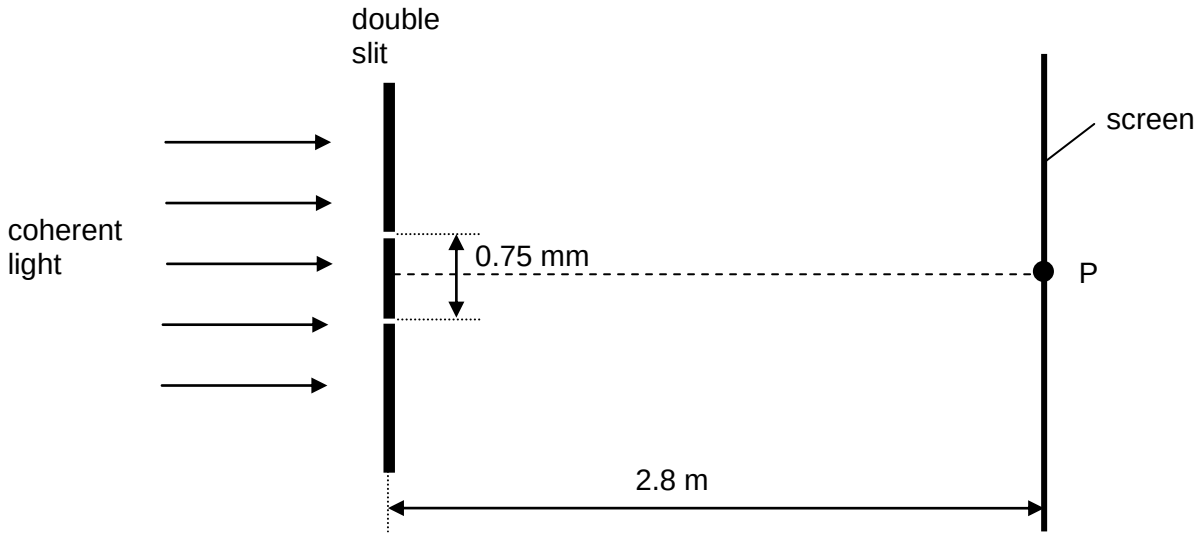

Fig. 2.1

The separation of the slits in the double slit arrangement is 0.75 mm.

A screen is placed parallel to, and at a distance of 2.8 m, from the double slit. P is a point on the screen that is equidistant from the two slits.

The interference pattern formed on the screen has a fringe separation of 1.2 mm.

(i) Calculate the wavelength, in nm, of the coherent light.

wavelength = …….. nm [2]

(ii) The intensity of the light on one of the slits is reduced to 25% of the intensity of light from the other slit.

Determine, for the bright fringe at P and the dark fringe closest to point P, the ratio

$$\frac{\text{amplitude of light at the bright fringe}}{\text{amplitude of light at the dark fringe}}.$$

ratio = …… [3]

3 In order to investigate the value of the internal resistance of a battery *r*, a student sets up a circuit as shown in Fig. 3.1.

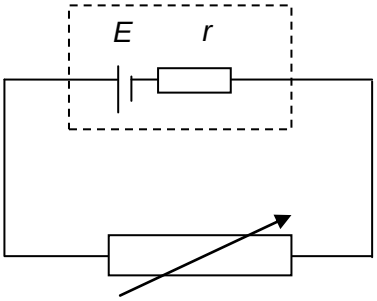

Fig. 3.1

The power dissipated in the variable resistor is P_v. The variation of P_v with resistance *R* of the variable resistor is shown in Fig 3.2.

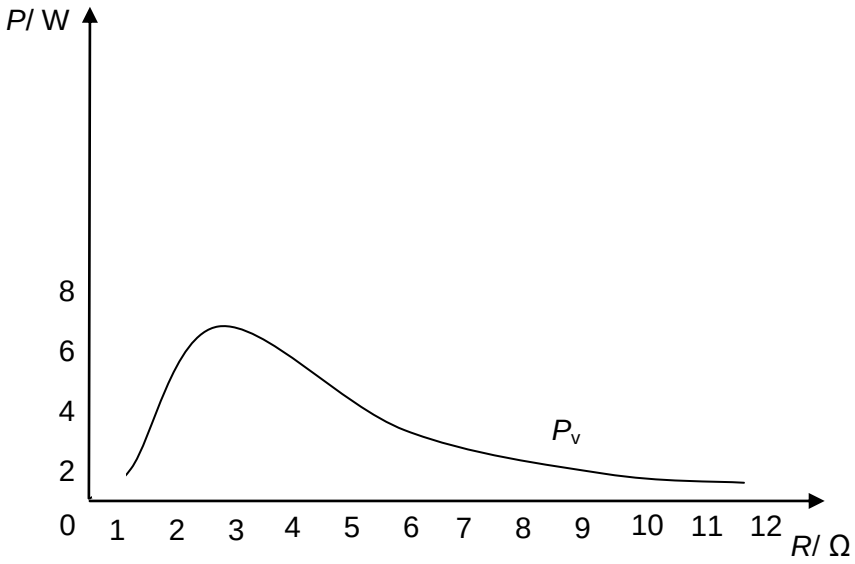

Fig. 3.2

(a) Explain how the student can deduce that the value of the internal resistance of the circuit, *r* is 3 Ω.

……..…

……..…

…….…… [1]

(b) For resistance R = 3 Ω, calculate the efficiency of transfer of power from the supply to the variable resistor.

efficiency = ……% [2]

(c) Sketch, without any further calculations, the variation of the total power with resistance of the variable resistor in Fig. 3.2. Label the graph as $P_{\mathbf{Total}}$. [1]

(d) A student is asked to design a circuit that provides maximum efficiency of energy transfer to a component. Thus, he correctly selected a battery that has an internal resistance that is much lower than the resistance of the load.

Explain the reason for his choice.

……

……

……

…….. [1]

4 A simple iron core transformer is shown in Fig 4.1.

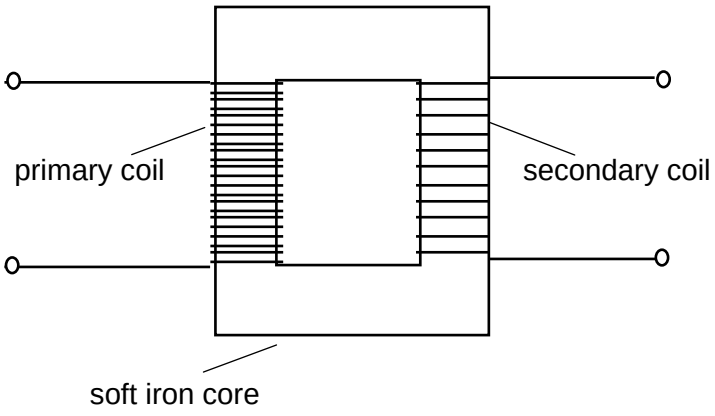

Fig. 4.1

(a) State Faraday's law of electromagnetic induction.

……..……..

……..……..……....

……..…… [2]

(b) Use Faraday's law to explain whether the current in the primary coil is in phase with the e.m.f induced in the secondary coil.

……..

……..

……..

……..

..…… [3]

5 An X-ray tube operates with a p.d across the tube of 90 kV. Fig. 5.1 shows the X-ray spectrum emitted.

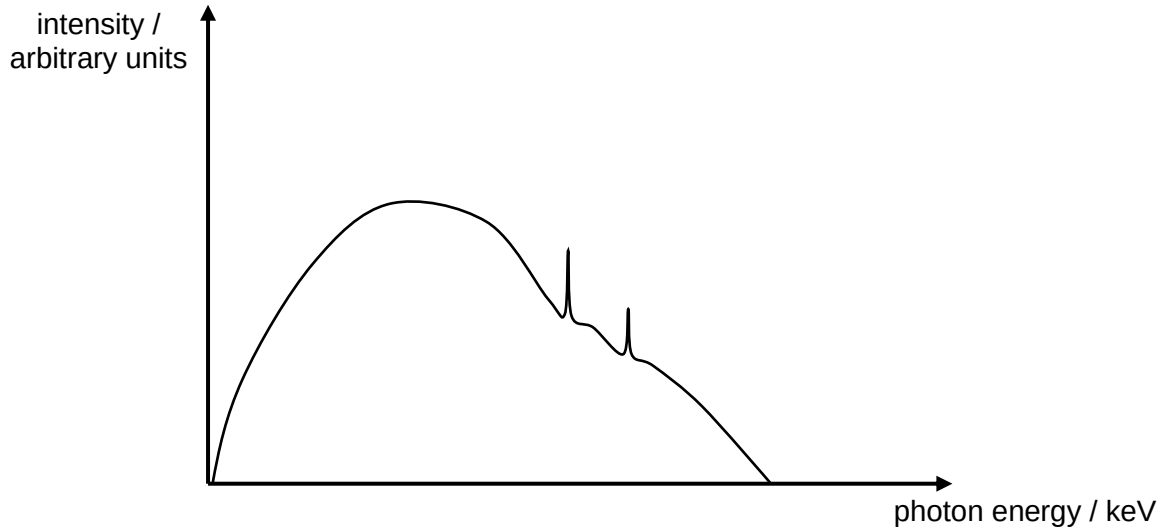

Fig. 5.1

(a) State the maximum photon energy detected in Fig.5.1.

maximum photon energy = …….. keV [1]

(b) Explain why the spectrum has sharp spikes at specific photon energies.

……

……

……

……..... [2]

(c) Sketch in Fig. 5.1 the expected X-ray spectrum when the p.d across the tube is reduced to 80 kV. [2]

6 **(a)** Describe how band theory is used to explain the difference between the conduction properties of insulators and **intrinsic** semiconductors.

……

……

……

……

……

……

……

…… [3]

(b) Explain the use of doping to change the conduction properties of semiconductors.

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……

……

…… [2]

7 When beryllium-9 is bombarded with α-particle of energy *E*, carbon atoms and neutrons are produced, together with a very penetrating γ-radiation. The nuclear reaction is

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{12}_{6}\text{C} + ^{1}_{0}\text{n} + \gamma$$

The binding energy per nucleon of the nuclei are

$^{9}_{4}\text{Be}$, 6.462758 MeV

$^{4}_{2}\text{He}$, 7.073915 MeV

$^{12}_{6}\text{C}$, 7.680144 MeV

(i) Define the following terms:

1. *nuclear fusion.*

……

…… [1]

2. *binding energy per nucleon*.

……

…… [1]

(ii) Determine the energy released in this reaction.

energy released = …… J [3]

(iii) The total kinetic energy of the carbon atom, neutron and the energy of radiation for each reaction is found to be more than the answer in **(ii)**. Suggest a reason for this difference.

……

…… [1]

Section B

Answer **two** questions from this Section in the spaces provided

8 A stationary radioactive nucleus polonium $^{210}_{84}Po$ undergoes α-decay process. In the α-decay process, a daughter nucleus X is formed with the simultaneous emission of an α-particle of energy 0.2 MeV and a photon of energy 6.1 MeV.

Data of the masses of the particles in the decay process are given in Fig. 8.1.

	mass / u
$^{210}_{84}Po$	209.98285
X	205.97447
α-particle	4.00151

Fig. 8.1

(a) **(i)** State the composition of the daughter nucleus X.

……[1]

(ii) The mass of the polonium (Po) nucleus is greater than the combined mass of the α-particle and X. Use a conservation law to explain qualitatively how this decay is possible.

……

……

……

……[2]

(iii) Show that the momentum of the daughter nucleus X is 1.1×10^{-19} N s. [3]

(b) **(i)** Explain what is meant by a *photon*.

……

……[1]

(ii) Determine the wavelength of the photon.

wavelength = ……..… m [2]

(iii) Show the linear momentum of the photon is 3.25×10^{-21} N s. [1]

(iv) Suggest why the photons emitted from the decay process of a large sample of radioactive particles exert a pressure on a metal surface when these photons are incident on it.

……

……

……

……

……

……

……[2]

(c) An illustration of another α-decay process is as shown in Fig. 8.2.

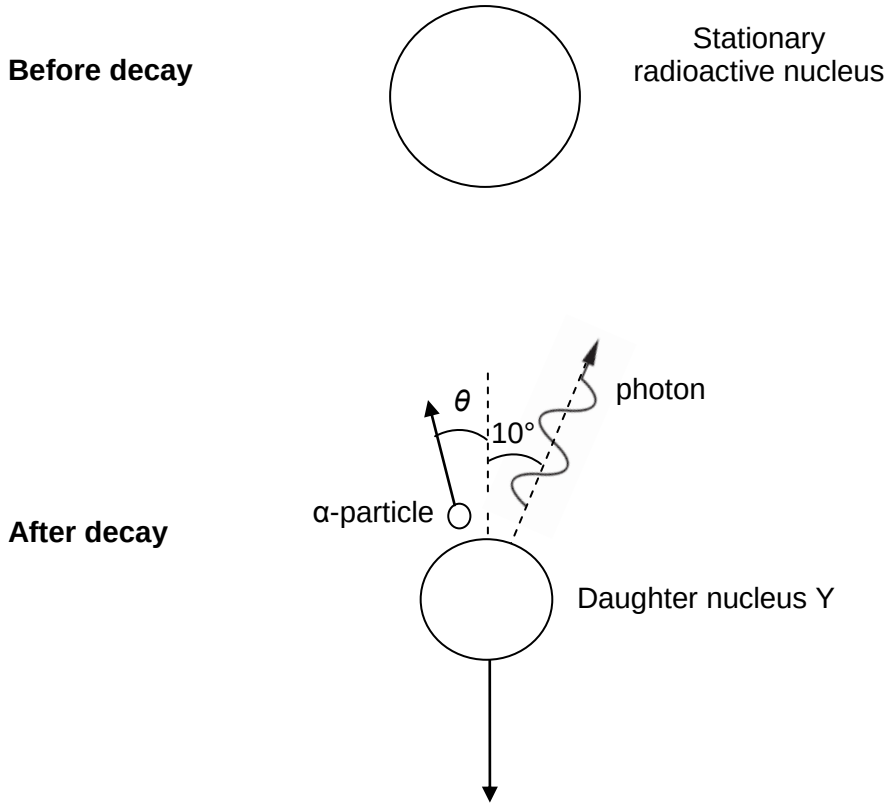


Fig. 8.2

After the emission, the daughter nucleus Y, α-particle and photon are emitted in the directions as shown in Fig. 8.2.

(i) State the principle of conservation of linear momentum.

……

……

……

……[2]

(ii) Explain why momentum is conserved during this emission.

……

……[1]

(iii) Momentum is a vector quantity and can be resolved into perpendicular components.

After the decay, the momentum of the daughter nucleus Y is 1.11×10^{-19} N s and the momentum of the photon is 3.25×10^{-21} N s.

Calculate the angle θ as shown in Fig. 8.2.

angle θ = ……..… ° [3]

(iv) If the daughter nucleus Y is stationary after the decay, deduce and explain the directions of motion of the α-particle and the photon.

……

……

……

……

……[2]

9 **(a)** Define *gravitational potential energy*.

……

……

……[1]

(b) Explain why is gravitational potential at a point is negative.

……

……

……

……

……[2]

(c) The Earth may be considered to be a uniform sphere with its mass of 5.98 x 10^{24} kg concentrated at its centre.

A satellite of mass 850 kg rotates in a uniform circular motion about the axis of the Earth with an orbital radius *R* with a gravitational potential energy of -5.0 x 10^{10} J.

(i) Calculate the value of *R*.

R = ……m [1]

(ii) Show that, for a satellite in orbit, the ratio of the gravitational potential energy of the satellite to its total energy is equal to 2. [3]

(iii) Hence, or otherwise, calculate the total energy possessed by the satellite as it moves in this orbit.

total energy = ……..J [1]

(iv) Determine quantitatively whether the satellite could be in geostationary orbit. [3]

(v) After certain time, the satellite moved into a circular new orbit. In this new orbit, it possessed a new kinetic energy of 8.0×10^{10} J.

1. Calculate the radius of this new orbit.

radius of new orbit = ……..……..m [1]

2. Explain why many satellites eventually 'burn up' in the Earth's atmosphere.

……

……

……

……

……

……

……

……

……..…… [2]

(d) The planet Jupiter has a mass of 1.89×10^{27} kg. A rock, initially at rest a long distance from Jupiter, travels towards Jupiter and reaches the surface with a speed of 6.0×10^{4} m s^{-1}.

(i) Show that the radius of Jupiter is 7.0×10^{7} m. [2]

(ii) Helium-4 may be assumed as an ideal gas.

Calculate the temperature of helium-4 gas at which the r.m.s. speed of the atoms is equal to the speed of the rock.

temperature = …….. K [2]

(iii) Suggest, with a reason, whether helium-4 gas is found on the surface of Jupiter.

……

……

……

……

…… [2]

10 A longitudinal sound wave of wavelength 2.1 m is travelling through a gas causing oscillations of gas molecules that are simple harmonic. The gas molecules are vibrating at a frequency of 835 Hz and have an amplitude of vibration of 610 nm.

(a) Explain what is meant by a *longitudinal* wave.

……

……

…… [2]

(b) For this sound wave in gas, state the origin of the restoring force on a molecule as it vibrates.

……

…… [1]

(c) **(i)** Determine, for one vibrating molecule,

1. the maximum speed,

maximum speed = …… m s^{-1} [2]

2. the magnitude of maximum acceleration,

maximum acceleration = …… m s^{-2} [2]

3. the magnitude of displacement from equilibrium where the vibrational kinetic energy of a gas molecule is half of the maximum vibrational kinetic energy,

displacement = …… m [2]

4. the shortest time interval for kinetic energy to vary from zero to maximum,

time interval = …… s [1]

(ii) Determine, for the sound wave,

1. the speed and

speed = …… m s^{-1} [1]

2. the amplitude.

amplitude = …… m [1]

(d) The transmission of sound waves can be affected by several factors such as the medium and the temperature.

(i) State an expression for total energy of a gas molecule due to oscillation caused by the sound wave. The gas molecule has mass *m*, and vibrates with frequency *f* and amplitude x_0.

……..……..[1]

(ii) Sound waves from a single source were directed to pass through Gas A and Gas B separately. Atoms of Gas A are more massive than that of Gas B. Compare and explain the effect on amplitude of sound waves when they passed through these two gases.

……

……

……

……..…… [2]

(e) A sound wave passes into a 4.0 m pipe that is open at both ends as shown in Fig. 10.1.

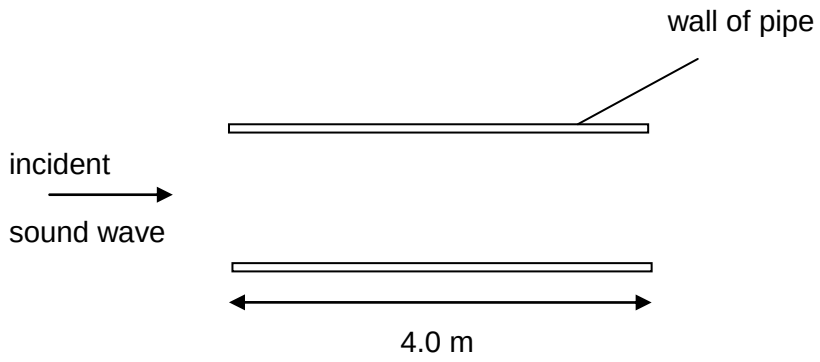


Fig. 10.1

The sound wave travels along the axis of the pipe.

(i) Explain the formation of a stationary (standing) wave in the pipe.

……

……

……

…… [2]

(ii) State 2 possible wavelengths that can form a stationary sound wave within this pipe.

…… [1]

(iii) Explain why only specific wavelengths will form stationary waves within this pipe.

……

…… [1]

(iv) While moving a microphone along the length inside the pipe, loud and soft sounds are detected. State whether loud or soft sound will be detected by the microphone at the open ends of the pipe.

…… [1]

END OF PAPER

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME			
CG		**INDEX NO.**	

PHYSICS **9646/01**

Preliminary Examination **22nd Sept 2016**
Paper 1 Multiple Choice **1 hour 15 minutes**

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 **forty** 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	/ 40

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm\omega\sqrt{x_0^2 - x^2}$

mean kinetic energy of a molecule $E = \frac{3}{2}kT$

of an ideal gas

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = Q/ 4 \pi \varepsilon_0 r$

alternating current/ voltage, $x = x_0 \sin \omega t$

transmission coefficient, $T \alpha \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions

1 A quantity R is found using the following expression

$$P = \frac{1}{8}Q - 2R$$

where $P = 0.70 \pm 0.03$
$Q = 25.0 \pm 0.5$

What is the value of R, together with its uncertainty?

A 1.21 ± 0.02
B 1.21 ± 0.05
C 1.213 ± 0.05
D 1.2 ± 0.5

Ans: **B**

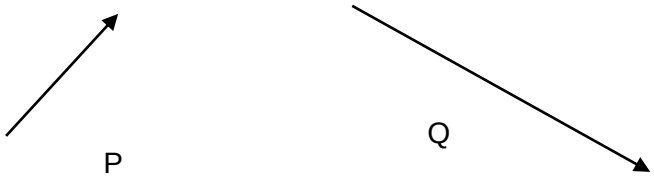
$$R = \frac{1}{2}\left(\frac{1}{8}Q - P\right) = \frac{1}{2}\left(\frac{1}{8} \times 25.0 - 0.7\right) = 1.2125$$

$$\Delta R = \frac{1}{2}\left(\frac{1}{8} \times 0.5 + 0.03\right) = 0.04625 \approx 0.05$$

$$R + \Delta R = 1.21 \pm 0.05$$

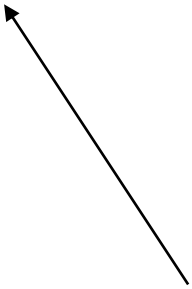
A: If subtract uncertainty, uncertainty = 0.02
C: Wrong DP for R.
D: Ignored coefficients when calculating uncertainty, uncertainty = 0.5

2 Vectors P and Q are drawn to scale.

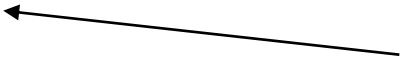


Which diagram represents the vector (P – Q)?

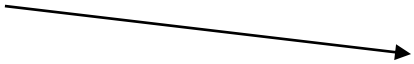
A



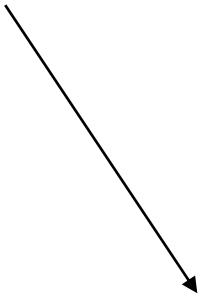
B



C

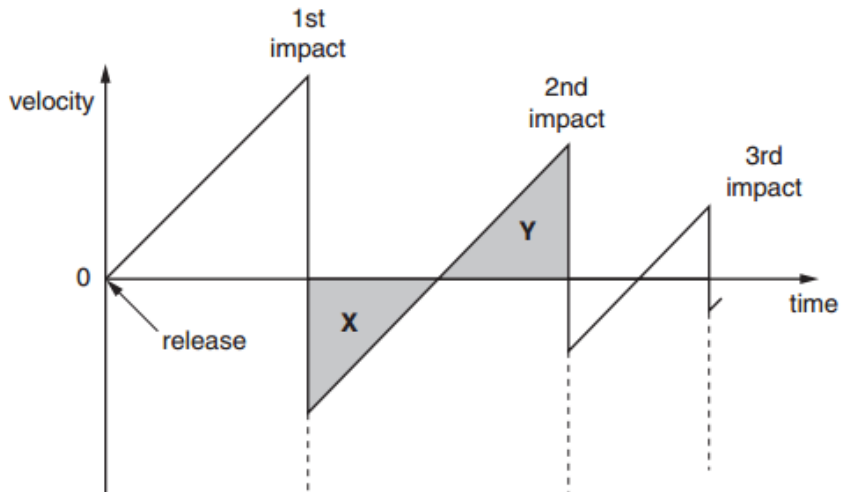


D



Ans: **A**

3 A ball is released from rest above a horizontal surface. The graph shows the variation with time of its velocity.



Areas **X** and **Y** are equal.

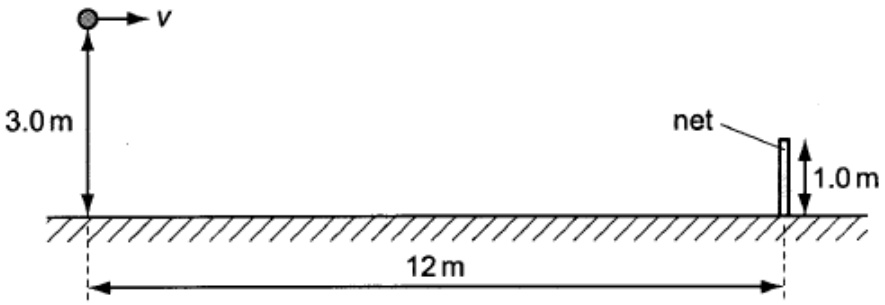
This is because

A the ball's acceleration is the same during its upward and downward motion.
B the speed at which the ball leaves the surface after an impact is equal to the speed at which it returns to the surface for the next impact.
C for one impact, the speed at which the ball hits the surface equals the speed at which it leaves the surface.
D the ball rises and falls through the same distance between impacts.

Ans: **D**

A: This is true but it accounts for the fact that the gradient is the same from the 1st impact to 2nd impact.
B: This is true but it accounts mainly for the speed after impact = speed just before next impact.
C: This is not true, as seen from the speed just before 1st impact (1st positive peak) differing from the speed just after 1st impact (1st negative peak).
D: Area under graph gives the displacement of the ball between 1st impact and 2nd impact.

4 A tennis ball is hit horizontally with speed *v* from a height of 3.0 m such that it just clears a net which is 1.0 m high. The ball is at a horizontal distance of 12.0 m from the net initially.



What is the value of *v*? Neglect the effects of air resistance.

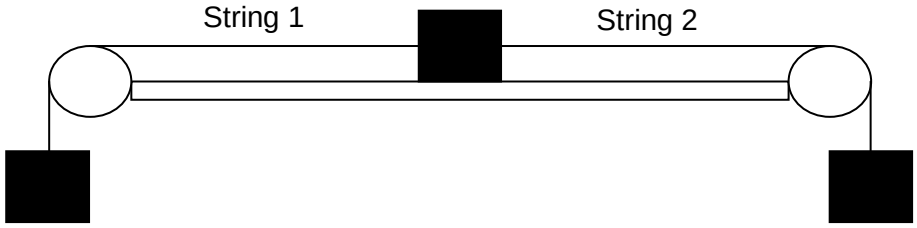
A 16 m s^{-1} **B** 19 m s^{-1} **C** 30 m s^{-1} **D** 38 m s^{-1}

Ans: **B**

Vertically, $2.0 = (0) + ½ (9.81) t^2$
$t = 0.6386$ s

Horizontally, $12 \text{ m} = u \times 0.6386$
$v = 19 \text{ m s}^{-1}$

5 Three identical blocks are connected by two strings through frictionless pulleys, as shown below. The middle block rests on a smooth table.



What is the ratio of $\frac{\text{tension in String 2 after String 1 was cut}}{\text{tension in String 2 before String 1 was cut}}$?

A 0.25 **B** 0.5 **C** 1 **D** 2

B
Tension in string 2 before string 1 cut = mg
After string 2 was cut,
considering FBD of middle mass and mass on the right,
T=ma mg-T=ma
Solving T= 0.5 mg ➔Ratio = 0.5

6 A cart X, moving along a horizontal frictionless track, collides with a stationary cart Y. The two carts become attached and move off together.

Which statement about this interaction is correct?

A Cart X loses some of its momentum as heat in the collision.

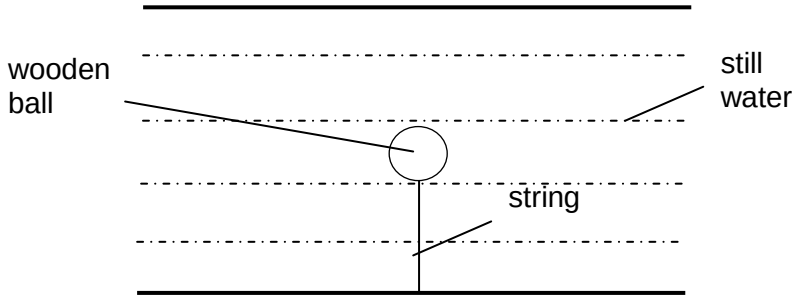
B Cart X shares its momentum with Cart Y but some of its kinetic energy is lost.

C Some of the momentum of trolley X is changed to kinetic energy in the collision.

D Some of the kinetic energy of trolley X is changed to momentum in the collision.

B Inelastic collision. Momentum of the system is conversed but KE is not

7 A wooden ball of density 800 kg m^{-3} and volume 1.0 m^3 is fastened to the bottom of a freshwater pond. The density of freshwater is 1000 kg m^{-3}.



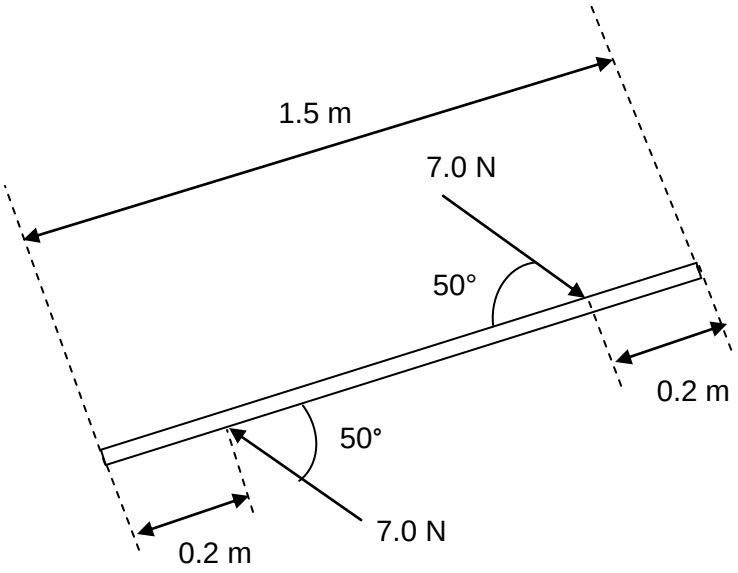
F_{net} = ma
U – W = ma
$V\rho_f g - V\rho_s g = V\rho_s a$
a = 2.50 m s^{-2}

Ans: C

If the string suddenly breaks, what is the initial acceleration of the ball?

A 0.25 m s^{-2} **B** 1.25 m s^{-2} **C** 2.50 m s^{-2} **D** 12.50 m s^{-2}

8 Two 7.0 N forces act on a beam of length 1.5 m. The forces are parallel and act in opposite directions at a distance of 0.2 m from each end of the beam. The angle between the forces and the beam is 50°.



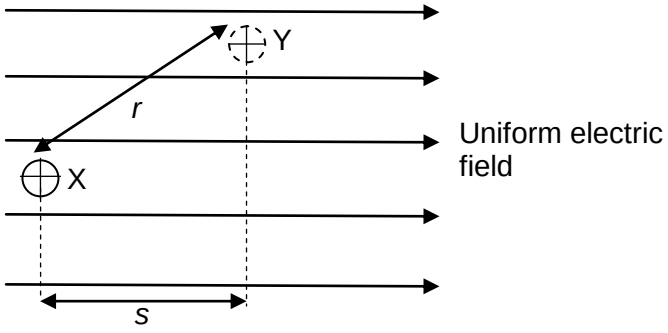
What is the torque of the couple exerted on the beam?

A 4.95 Nm **B** 5.90 Nm **C** 6.75 Nm **D** 8.04 Nm

Ans: **B**
$\tau = F \times d = 7.0 \sin 50 \times 1.1$
$\tau = 5.90 \text{Nm}$

A: $\tau = F \times d = 7.0 \cos 50 \times 1.1 = 4.95$
B: $\tau = F \times d = 7.0 \cos 50 \times 1.5 = 6.75$
C: $\tau = F \times d = 7.0 \sin 50 \times 1.1 = 8.04$

9 A positive ion is placed at point X in a uniform electric field. Due to the electric field, it experienced an electric force *F* and it is moved from point X to point Y.



What is the change in the electric potential energy of the ion?

A decreases by *Fs*

B increases by *Fs*

C decreases by *Fr*

D increases by *Fr*

The electric force is pointing in the same direction as the electric field for a positive charge. Since force always acts in the direction of decreasing potential energy, the EPE is decreasing by *Fs* as ion moves from X to Y.

Ans: A

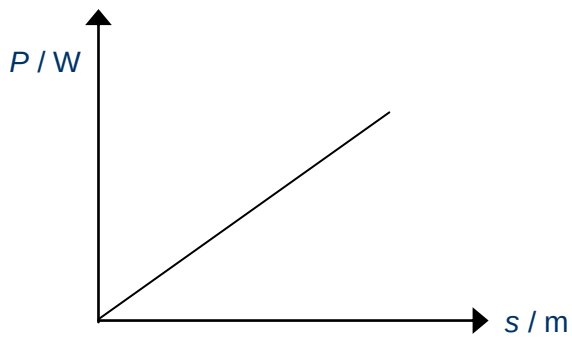
10 A car starts from rest and its driving force causes its speed to increase at a constant rate.

Which graph shows the variation of the power output of the vehicle *P* with the distance travelled by the car *s*?

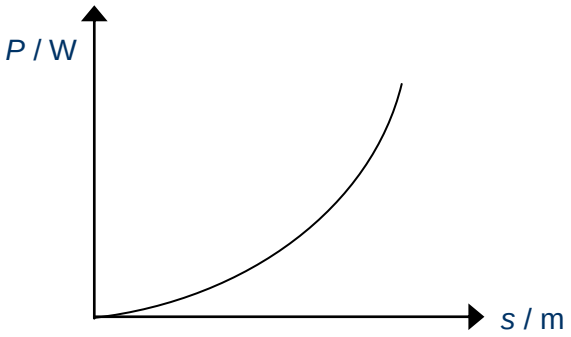
A



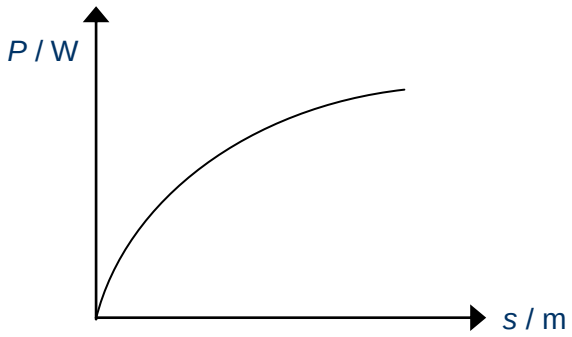
B



C



D



P = Fv.
Since speed increases at a constant rate, the car has a constant acceleration.

Using equation of kinematics , $v^2 = u^2 + 2as$

Since start from rest, u = 0
$v^2 = 2as$
$v = (2as)^{1/2}$

$P = ma(2as)^{1/2}$

Since m and a are constants, the graph of P against s would be a graph of $P \alpha s^{1/2}$

Ans: D

11 An object undergoing uniform circular motion with radius r rotates by an angle of θ in time t.

What are the magnitudes of linear velocity and acceleration?

	linear velocity	acceleration
A	$\frac{\theta r}{t}$	$\frac{\theta^2 r}{t^2}$
B	$\frac{2\pi r}{t}$	$\frac{4\pi^2 r}{t^2}$
C	$\frac{2\pi r}{t}$	$\frac{\theta^2 r}{t^2}$
D	$\frac{\theta r}{t}$	$\frac{4\pi^2 r}{t^2}$

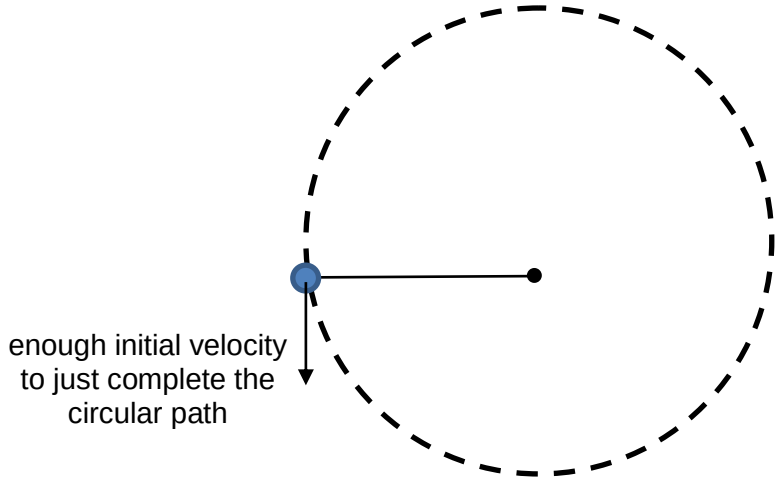
Ans: A

$$\omega = \frac{\theta}{t}$$

$$v = r\omega = \frac{\theta r}{t} \quad .$$

$$a = r\omega^2 = \frac{\theta^2 r}{t^2}$$

12 An object of mass of m is tied to a string and projected with enough initial velocity such that it is just able to complete a vertical circular path.



What is the maximum tension the string experiences throughout the circular path?

A $2mg$ **B** $3mg$ **C** $5mg$ **D** $6mg$

Ans D
At top,
To just complete circle, there is a minimum velocity at the top

$$mg - T = \frac{mv_{top}^{\ 2}}{r} \quad (As\ T = 0\ for\ minimum\ speed.)$$

$$v_{top}^{\ 2} = rg$$

To find speed of object at bottom of circle by principle of conservation of energy

$$mg2r = \frac{1}{2}mv_{bottom}^{\ 2} - \frac{1}{2}mv_{top}^{\ 2}$$

$$v_{bottom}^{\ 2} = 5rg$$

At bottom,

$$T - mg = \frac{mv_{bottom}^{\ 2}}{r}$$

$$T - mg = \frac{m(5rg)}{r} = 5mg$$

$$T = 6mg$$

13 It is known that the acceleration of free fall measured at the poles would be different from that which is measured at the Equator.

How does the measurement at the poles differ from that at the Equator? The Earth is assumed to be a sphere with radius 6400 km.

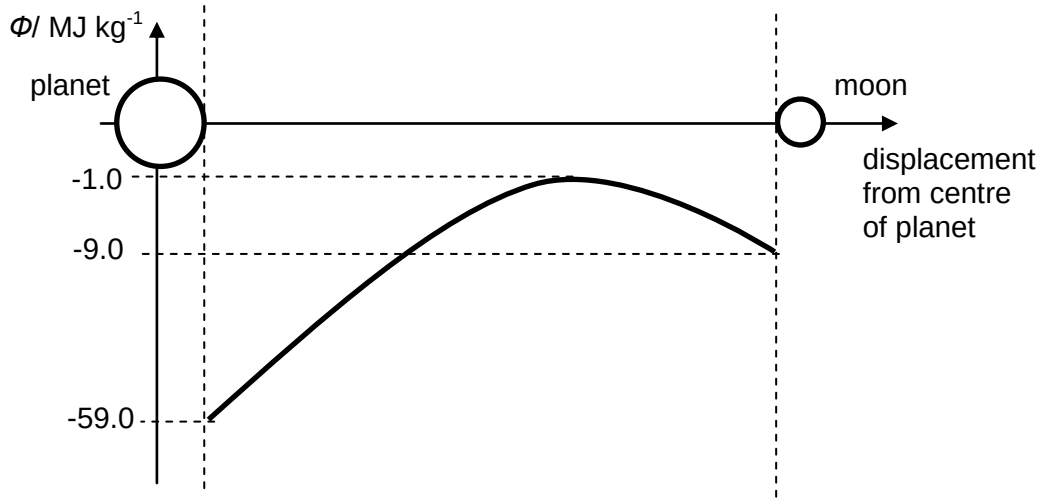
A Measurement at poles is 0.0338 m s^{-2} more than measurement at Equator.
B Measurement at poles is 0.0338 m s^{-2} less than measurement at Equator.
C Measurement at poles is 254 x 10^{-9} m s^{-2} more than measurement at Equator.
D Measurement at poles is 254 x 10^{-9} m s^{-2} less than measurement at Equator.

Ans A

For an object on a Force balance at the Pole.
N = mg. (The apparent weight = true weight)
Apparent weight = mg = ma. (Where a is measured acceleration)
a = g.

For an object on a Force balance at the Equator
$mg - N = m\omega^2 r$ (Where N is the apparent weight)
$N = mg - m\omega^2 r$
$ma = mg - m\omega^2 r$ (where a is measured acceleration)
$a = g - \omega^2 r$
Measurement of a at pole is $\omega^2 r$ more than measurement at equator.

14 The figure below shows the variation of gravitational potential Φ between a planet and its moon.



An object of 2 kg is projected from the moon's surface towards the planet's surface.

What is the minimum kinetic energy that the object will have when it hits the planet's surface?

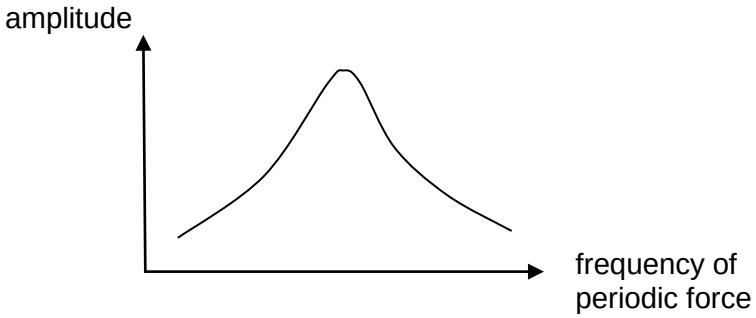
A 8.0 MJ **B** 16.0 MJ **C** 100.0 MJ **D** 116.0 MJ

Ans D

For the object to land on the planet's surface with minimum energy, the object should have 0 KE at the position of peak gravitational potential.

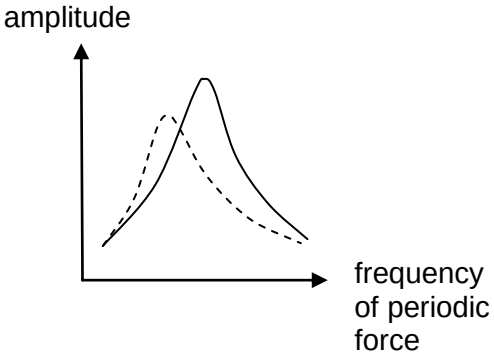
Considering position between peak gravitational potential and planet's surface
Gain in KE = Loss in GPE
Gain in KE = m(-1.0 – (-59.0)) MJ
Gain in KE = 2(58.0) = 116 MJ

15 An external periodic force is applied on a spring-mass oscillating system to cause forced oscillation. The frequency of the external periodic force is varied to obtain the corresponding amplitude of oscillation and the results are as shown (solid line) in the diagram below.

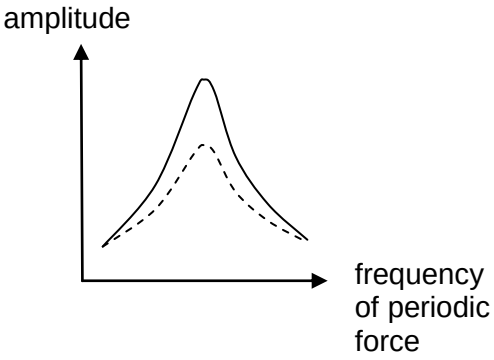


Which of the following graphs (dotted line) shows the correct variation of amplitude with frequency when only the mass of the oscillating system is increased?

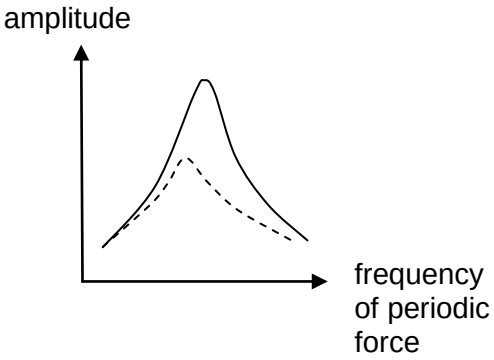
A



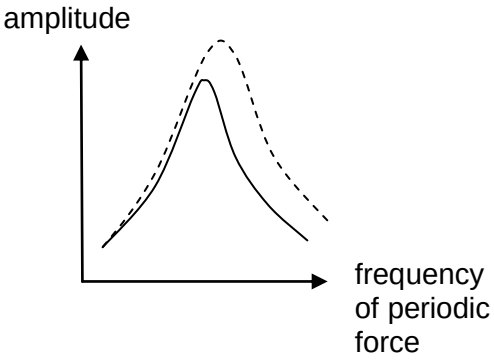
B



C



D



Answer: C
There is increased mass and hence, amplitude at all frequencies should be lower. The maximum amplitude should occur at lower frequency as well.

16 A mass attached to a spring is undergoing simple harmonic oscillations vertically. Interchange between kinetic energy (KE), gravitational potential energy (GPE) and elastic potential energy (EPE) takes place.

Which of the following is a correct description of these energies as the mass moved from the highest point to lowest point of oscillation?

A GPE decreased linearly and was converted to EPE. Hence EPE also varies linearly.

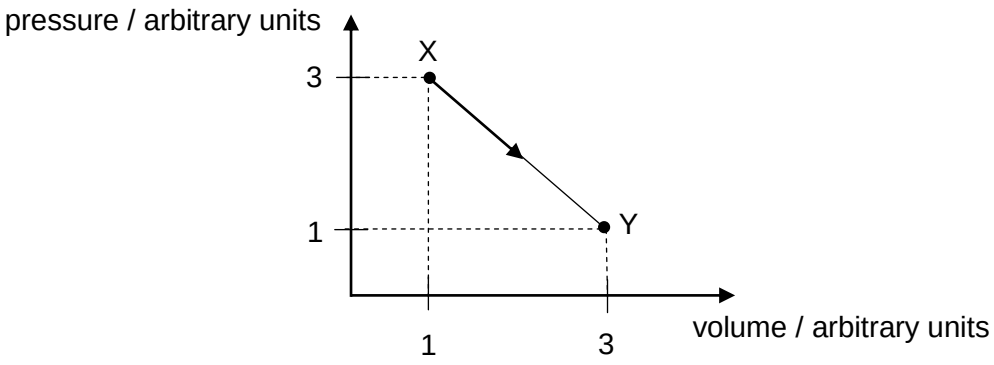
B EPE and GPE decreases non-linearly to zero at equilibrium position and hence KE is maximum at equilibrium.

C Since KE varies non-linearly and GPE varies linearly, EPE must vary non-linearly.

D At equilibrium position, half of the GPE lost will always be converted to EPE and the other half will always be converted to KE.

Answer: C
Conservation of energy.

17 A fixed amount of ideal gas undergoes a process XY as shown,



Which of the following statements is true of the process XY?

A There is zero heat supplied to gas.
B There is positive heat supplied to gas.
C There is an increase in internal energy of gas.
D There is a decrease in the internal energy of gas.

Ans B

Since PV remains constant for the process, the temperature and hence the internal energy of the gas is a constant.

Using 1st law of thermodynamics,
ΔU = Q + W (ΔU = 0 as temperature change is zero)
0 = Q + W (Where Q is heat supplied and W is work done <u>on</u> gas)
Q = -W
Since the gas expands the work is done <u>by</u> gas implying that W is negative, hence the Q must be a positive value.

18 Which of the following statements regarding specific latent heat of fusion l_f and vaporisation l_v in general is true?

A l_f is higher than l_v because more energy is required to break the strong bonds of a solid during melting than for breaking the bonds in a liquid during vaporisation.

B l_f is higher than l_v because less energy is required during the vaporisation as some of the molecules of the liquid already have enough energy to break free from the liquid even below the boiling point.

C l_v is higher than l_f because more energy is required during the vaporisation as a significant amount of energy is required to do work against the atmosphere.

D l_v is higher than l_f because vaporisation occurs at a higher temperature than fusion.

Ans C

Fact.

19 The energy carried by a wave is proportional to

A the square of the wave's amplitude as well as the square of intensity.

B the square of the wave's amplitude as well as the intensity.

C the wave's amplitude as well as the square of intensity.

D the wave's amplitude as well as the intensity.

Ans: B intensity $\propto$ Amplitude^2 $\propto$ Energy

20 A point source of sound radiates energy uniformly in all directions. The amplitude of oscillation of the air molecules at a distance of 3.2 m from the source is 64 μm. Assuming that the sound is propagated without energy loss, what is the distance from the source when the amplitude of the oscillation of the air molecules is 8 μm?

A 26 m **B** 82 m **C** 205 m **D** 655 m

A Since $I \propto A^2$ and $I \propto \frac{1}{r^2}$

$$A^2 \propto \frac{1}{r^2}$$

$$\left(\frac{r_{3.2\,m}}{r}\right) = \left(\frac{A}{A_{3.2\,m}}\right)$$

$$\left(\frac{3.2}{r}\right) = \left(\frac{8}{64}\right)$$

$$r = 25.6m$$

21 Monochromatic light of wavelength 600 nm is incident normally on a diffraction grating. The grating has 500 lines per mm.

What is the angle between the two second-order diffracted beam?

A 17.5^0 **B** 35^0 **C** 37^0 **D** 74^0

Answer: A

Correct answer:

$\frac{0.001}{500}\sin\theta = 2(600\times10^{-9})$

$\theta = 37°$

Answer : $74°$

$\frac{0.001}{500}\sin\theta = 2(600\times10^{-9})$

Wrong answer: $\theta = 37°$

Answer : $37°$

$\frac{0.001}{500}\sin\theta = (600\times10^{-9})$

Wrong answer: $\theta = 17.5°$

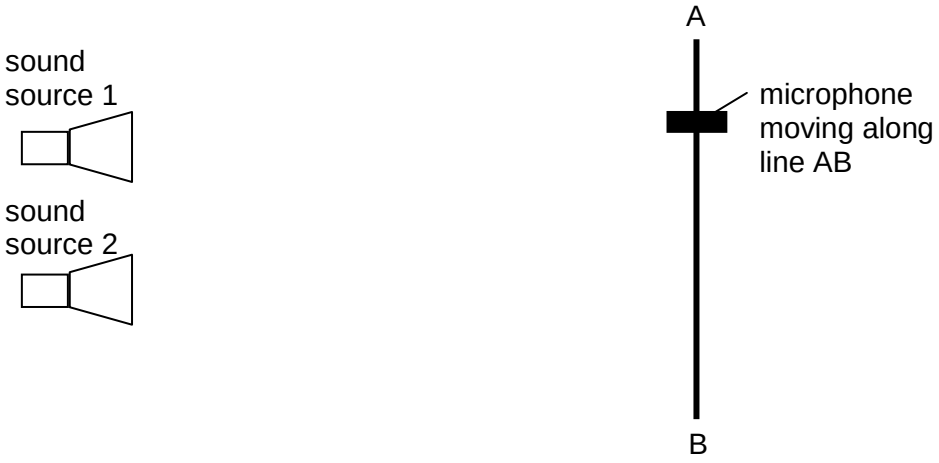
Answer : $35°$

$\frac{0.001}{500}\sin\theta = (600\times10^{-9})$

Wrong answer: $\theta = 17.5°$

Answer : $17.5°$

22 A student set up a two-source interference experiment with sound sources positioned as shown below. However, there was no observable interference pattern when a microphone is moved along line AB.



Which of the following could be a likely cause for the lack of observable interference pattern?

A The distance from sound sources to detector is not much larger than the spacing between the sources.

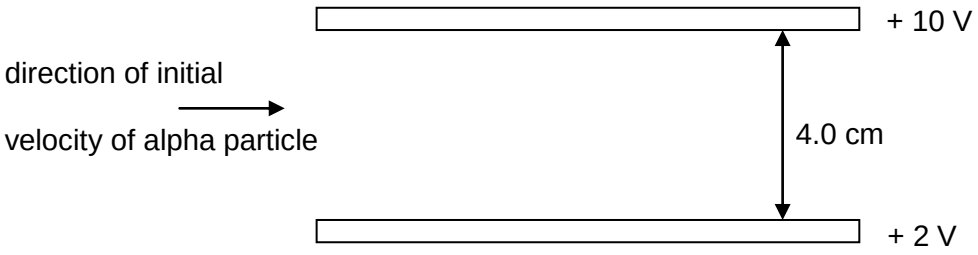
B The intensities of sound from the two sources are not approximately the same.

C The sound sources are coherent but not in phase.

D Waves from the sound sources always meet antiphase along line AB.

Answer: B
Fact.

23 An alpha particle is projected into a region between two parallel positively charged plates with a velocity parallel to the plates, as shown in the diagram below.



Upon exiting the region between the plates, it deflects vertically by 1.0 cm.

What is the change in kinetic energy of the particle?

A 1.6×10^{-19} J **B** 3.2×10^{-19} J **C** 6.4×10^{-19} J D 12.8×10^{-19} J

Answer: C
Gain in KE = Loss in EPE

Gain in KE $= qV = (2)(1.6\times10^{-19})(\frac{1}{4})(8) = 6.4\times10^{-19}$ J

24 Which of the properties of objects below best accounts for the force due to each field?

	Field	Property
A	Gravitational	mass
	Electric field	moving charge
	Magnetic field	magnetic poles
B	Gravitational	weight
	Electric field	charge
	Magnetic field	magnetic poles
C	Gravitational	mass
	Electric field	positive charge
	Magnetic field	moving charge
D	Gravitational	mass
	Electric field	stationary charge
	Magnetic field	magnetic poles and moving charge

Answer: D
Fact.

25 The potential difference between point X and point Y in a circuit is 20 V. Within 15 s, the energy of the charge carriers changes by 12 J.

What is the current betweeen X and Y?

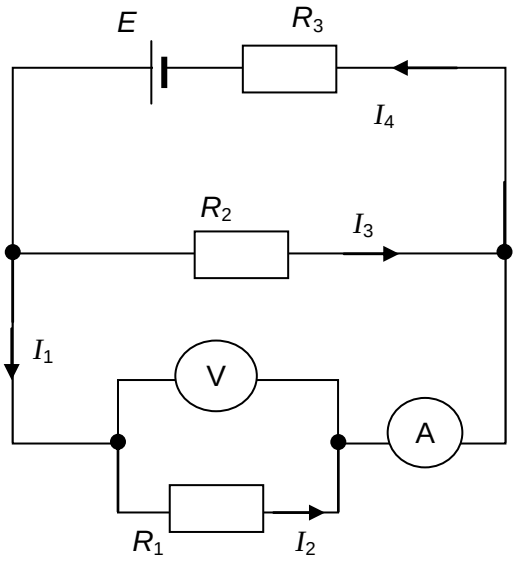
A 0.040 A **B** 0.11 A **C** 9.0 A **D** 25 A

Since V = W/ Q
Q = W / V
= 12 / 20 = 0.6 C

Since Q = It
I = 0.6 / 15 = 0.04 A

Ans: A

26 The figure below shows a circuit that comprises of a battery, 3 resistors, a voltmeter and an ammeter. The e.m.f. of the battery is *E*.



No current flows through voltmeter. Hence $I_1 = I_2$.

Current through ammeter = $I_1 = I_2$

Voltmeter reading = R_1I_2
= R_2I_3
= E - I_4R_3

Ans: C

Which of the following shows the correct expression for the voltmeter reading and ammeter reading?

	Ammeter reading / A	Voltmeter reading / V
A	I_2	$I_4R_3 + I_3 R_2$
B	$I_3 + I_4$	E
C	I_1	$E - I_4R_3$
D	$I_1 + I_3$	I_2R_1

27 When a 4 Ω resistor is connected between the terminals of a certain cell, a 2 A current flows through the circuit. When the 4 Ω resistor is replaced by a 2 Ω resistor, the current changes to 3 A.

Which of the following show the correct values of the e.m.f. and the internal resistance of the cell?

	e.m.f / V	internal resistance / Ω
A	15	4
B	12	2
C	10	1
D	8	zero

By $V = E - Ir$

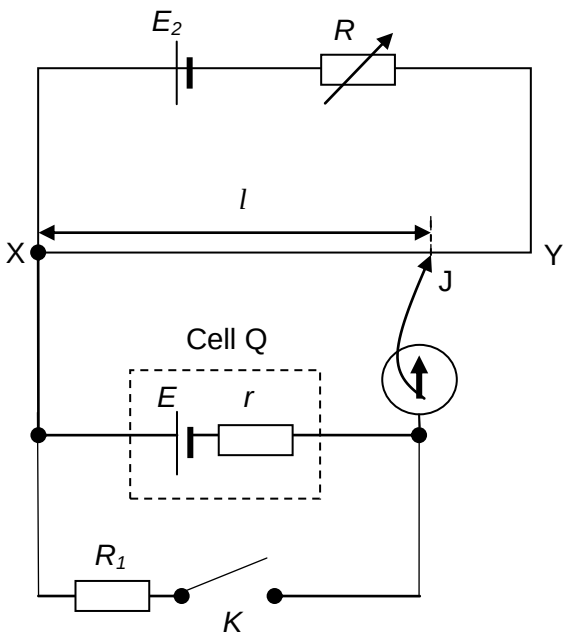
Equation 1: (4)(2) = E – 2r

Equation 2: (2)(3) = E – 3r

Solving equation 1 and 2,
r = 2 Ω and E = 12 V

Ans: B

28 In order to determine the value of e.m.f of cell Q, the following circuit is set up. XY is a wire with uniform resistance. When switch K is open, the balance length is l.



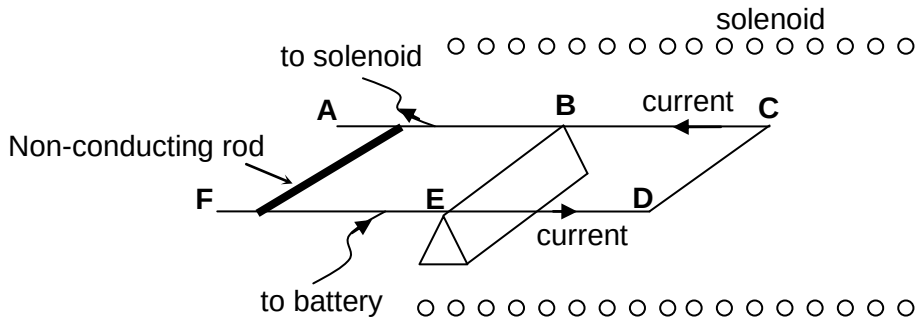
Since no current passes through cell Q at balance length (with switch K open), there will not a potential drop across the additional resistor placed in series with cell Q. Therefore, it will not affect the balance length.

Ans: A

Which of the following statements is false?

A Placing another resistor in series with cell Q will change the value of l.
B Increasing the value of the variable resistance R will increase the the value of l.
C When switch K is closed, the value of l will decrease.
D The value of the r is not required for the determination of E.

29 A current balance device was set up to determine the magnetic field strength created by a solenoid as shown below. The first experiment determined the magnetic field strength as *B*.



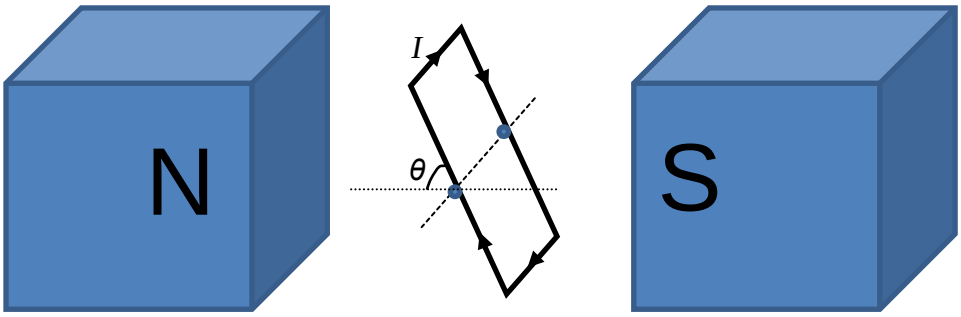
The setup was used again with one or some of the factors changed. A non-conducting rod of a larger mass had to be used in the second experiment.

Which one of the following could most likely be the changes made?

A Another frame with a shorter length for CD was used.
B The current passing through the solenoid and the number of turns of the solenoid are reduced.
C The first experiment was set up such that the direction of the Earth's magnetic field is opposite to the magnetic field created by the coil while the second experiment had both magnetic fields in the same direction.
D The knife edge was moved closer to CD.

C
Principle of moments.
Increased anticlockwise moments.

30 A rectangular coil with *N* turns is placed in a uniform horizontal magnetic field *B* which makes an angle θ with the plane of the coil as shown below. The coil carries a current I and has an area *A*.



What is the torque of the couple experienced by the coil?

A *NBAI* cosθ

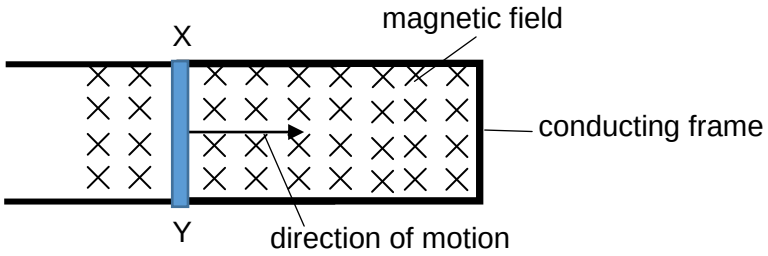
B 2*NBAI* cosθ

C *NBAI* sinθ

D 2*NBAI* sinθ

A
F = *NBIL*
Torque of couple = *NBIL* (A/L) cosθ = *NBAI* cosθ

31 The diagram below shows a wire conductor, XY, positioned perpendicular to a uniform magnetic field directed into the paper moving across a conducting frame.



Which of the following statements describes the relative potentials between X and Y and the direction of induced current in the conducting frame?

A Potential at X is higher than potential at Y, so current flows in the clockwise direction through the conducting frame.

B Potential at X is higher than potential at Y so current flows in the anticlockwise direction through the conducting frame.

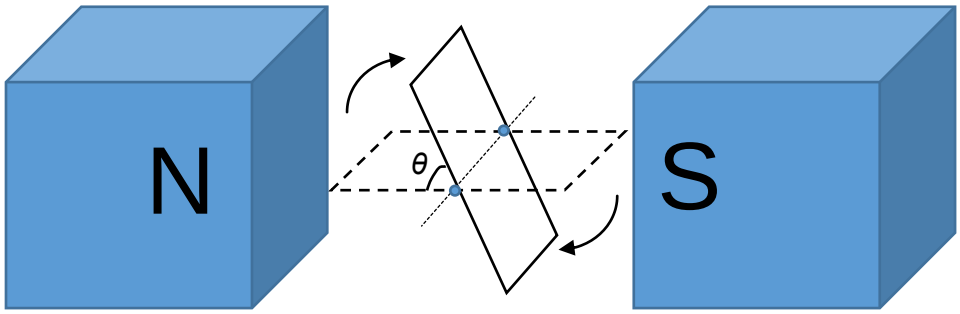
C Potential at Y is higher than potential at X, so current flows in the clockwise direction through the conducting frame.

D Potential at Y is higher than potential at X, so current flows in the anticlockwise direction through the conducting frame.

Ans A

Fleming's RHR. Current flows from Y to X so current in conductor is clockwise
Since XY is an e.m.f source, potential at X is higher than Y.

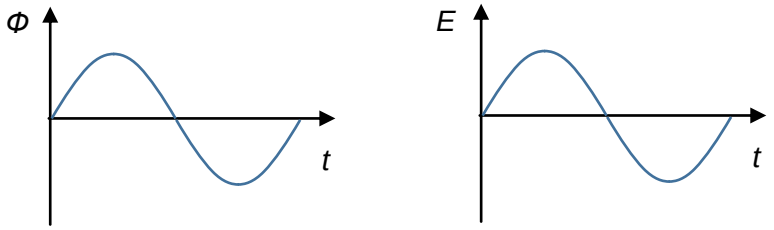
32 A rectangular coil is rotated in a magnetic field as shown.



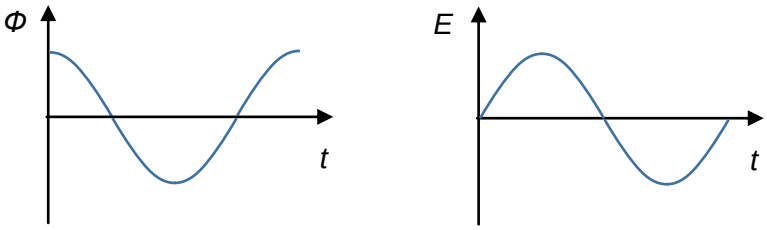
At time $t = 0$, angle $\theta = 0°$.

Which of the following options show the correct variation of flux Φ and induced e.m.f E with t for one full rotation?

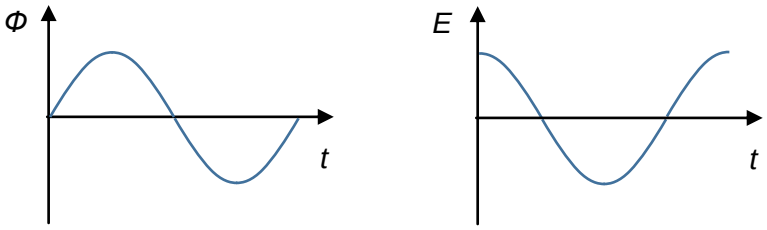
A



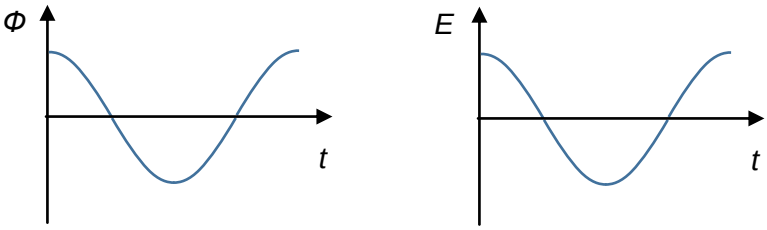
B



C



D



Ans C

33 As seen in Fig. (a), 4 diodes are placed in a circuit with a resistor *R* and alternating current (AC) source that changes the direction of current after each cycle. The positions of the 4 diodes are represented by the dotted boxes.

When a CRO is placed across the resistor R to observe the variations of the current. The graph in Fig. (b) is obtained.

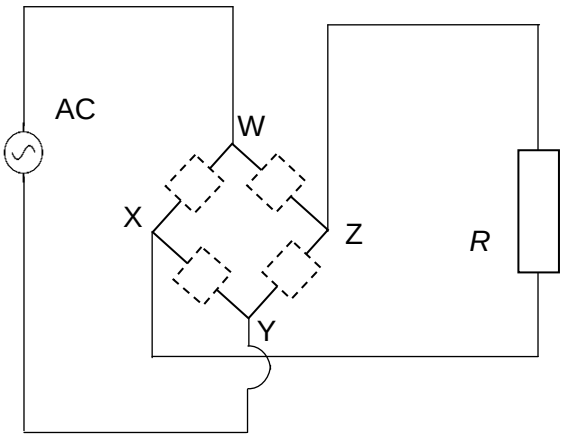


Fig. (a)

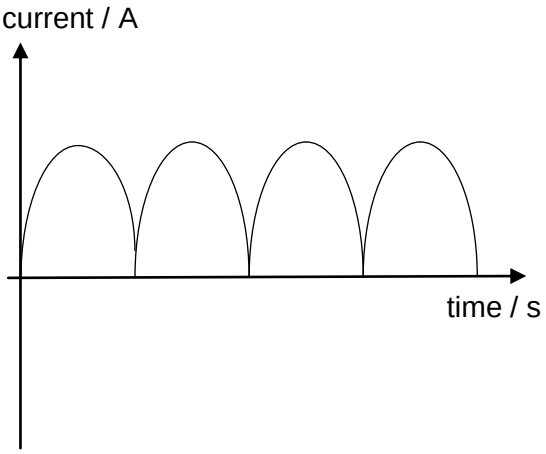
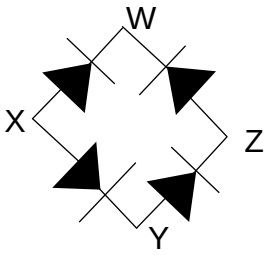


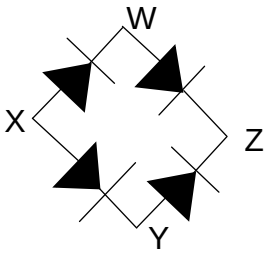
Fig. (b)

Which of the following shows the correct placement of the diodes?

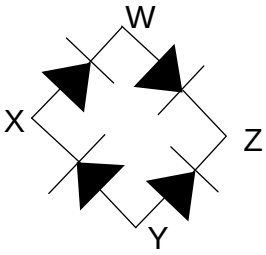
A



B



C



D

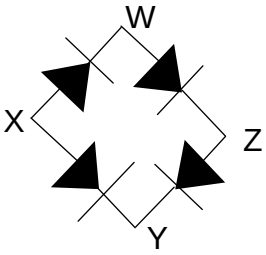
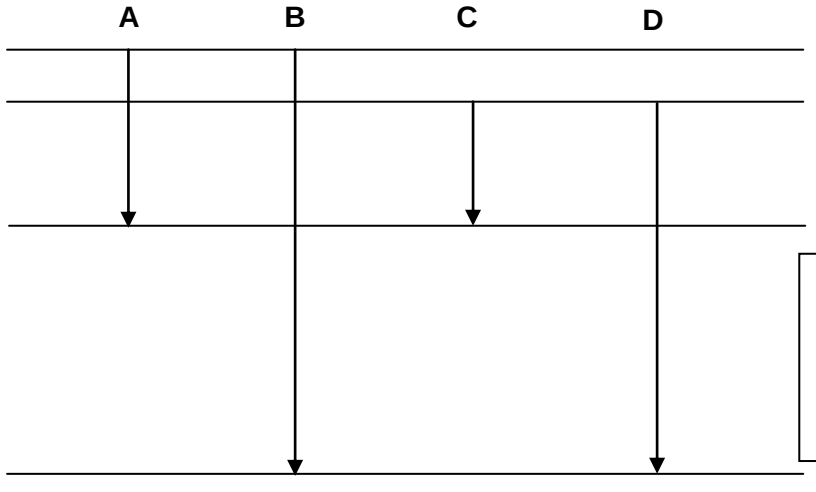


Fig. (b) shows full wave rectification. Hence current must "enter" R from the same way regardless of the changing direction of the current from the AC source.

Ans: B

34 The energy levels of an atom of an element are shown in the following diagram. Which energy transitions will produce photons of wavelength 620 nm?



$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{620\times10^{-9}}$$
$$= 2.0 \text{ eV}$$

Ans: C

35 An electron is moving at 10^{-4} times that of the speed of light. What is the region of the electromagnetic spectrum of its wavelength?

A Microwave
B X-ray
C Visible light
D Radio waves

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times10^{-4}\times3\times10^{8}} = 24\text{nm}$$

→ In the range of X-rays.

Ans: B

36 A particle is defined by position (x, y, z) and corresponding momenta (p_x, p_y, p_z). According to Heisenberg's Uncertainty principle, which of the following observables cannot be measured simultaneously?

A x and p_y **B** y and p_y, **C** p_y and p_z **D** x and z

Ans B

For HUP, the conjugate variables momentum and position must be in the same direction.

37 Which of the following statements regarding "Quantum Tunnelling" of electrons is false?

A When the width of the potential barrier decreases, the reflection coefficient decreases.

B When the height of the potential barrier increases, the transmission coefficient decreases.

C The energy of the electron which has successfully tunnelled across a potential barrier is less than the energy it has before the barrier.

D The amplitude of the wave function across the barrier is lower than the amplitude of the wave function before the barrier.

Ans C

The energy of the electron remains the same after tunnelling (even though the amplitude of the wave function ψ decreases (giving an indication of the $|\psi|^2$ the probability density function being lower across the barrier hence having a lower probability of the electron being across the barrier.)

38 Which of the following statements concerning a laser system is true?

A An external energy source is needed to create a metastable state so that population inversion can occur.

B A laser beam is monochromatic because there is a fixed energy gap between the meta-stable state of the electrons and the lower electron energy level.

C A laser beam achieves its brightness because of the two fully reflecting mirrors placed at the ends of the tube containing the lasing substance.

D A laser beam is coherent and of a single wavelength because of spontaneous emission.

Ans: B
A: An external energy source pumps the electrons to the higher energy state. But doesn't create a metastable state.
C: One mirror is fully reflecting whereas the other mirror is partially reflecting.
D: because of stimulated emission.

39 For an alpha scattering experiment, which of the following statements is correct?

A As alpha particles passes through gold foil they diffract and land on different positions on the screen, leading to regions of maxima and minima.

B Alpha particles slow down when it hits the gold foil thus giving out X-ray photons.

C Most particles passed through undeflected because of barrier tunnelling.

D Back scattering coupled with most particles passing through undeflected suggest an atom model with concentrated small nucleus.

Answer: D

40 A sample of radioactive nuclide X with nucleon number 239 and half-life *T* decays by emission of an alpha particle to form daughter nuclide Y. The original sample is placed on a weighing machine and gave a reading of 478 g.

What is the reading after a time of 3*T*?

A 60 g **B** 411 g **C** 418 g **D** 471 g

Answer: D

$$mass = \frac{N}{N_0}(478) + \frac{(N_0 - N)}{N_A}(235)$$

$$= (\frac{1}{2})^3(478) + [1-(\frac{1}{2})^3](\frac{N_0}{N_A})(235)$$

$$= (\frac{1}{2})^3(478) + [1-(\frac{1}{2})^3](\frac{478}{239})(235)$$

$$= (\frac{1}{2})^3(478) + [1-(\frac{1}{2})^3](\frac{N_0}{N_A})(235)$$

$$= 471\,\text{g}$$

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

NAME

CG **INDEX NO.**

PHYSICS 9646/02

Preliminary Examination **14th Sept 2016**
Paper 2 Structured Questions **1 hour 45 minutes**

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	/ 4
Q2	/ 12
Q3	/ 6
Q4	/ 6
Q5	/ 6
Q6	/ 3
Q7	/ 8
Q8	/ 15
Q9	/ 12
Total marks	/ 72

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_0^2 - x^2}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q/ 4 \pi \varepsilon_0 r$
alternating current/ voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	α	$\exp(-2kd)$
where	k	=	$\sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions

1 Two parallel strings S_1 and S_2 are attached to a disc of diameter 12 cm, as shown in Fig. 1.1.

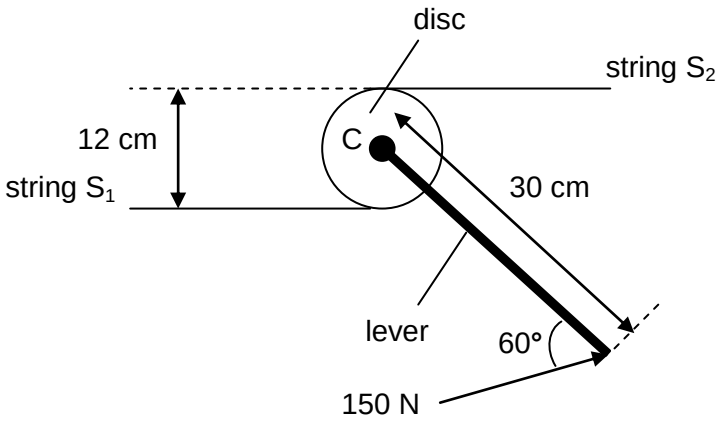


Fig. 1.1

The disc is free to rotate about an axis normal to its plane. The axis passes through the centre C of the disc.

A light lever of length 30 cm is attached to the disc. When a force of 150 N is applied on the lever at an angle of 60° at its end, equal forces are produced in S_1 and S_2. The disc remains in equilibrium.

Determine

(a) the moment of the 150 N force about the centre of the disc,

Moment = 150 sin 60° x 0.30 = 39.0 Nm [A1]

moment = …… N m [1]

(b) the force in S_1. Explain your working.

According to the principle of moments,
Sum of clockwise moments = Sum of anticlockwise moments. Therefore,
Torque due to both strings
= moment due to 150 N force = 39.0 Nm [M1]

Force = 39.0 ÷ 0.12 [M1]
= 325 N [A1]

force = …… N [3]

2 **(a)** To determine the specific heat capacity of a liquid, the apparatus is set up as shown in Fig. 2.1. An electric heater contains a tube through which the liquid flows at a constant rate. The liquid in the tube passes over a heating coil, as shown in Fig. 2.1.

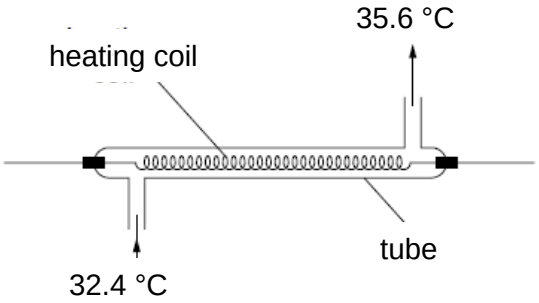


Fig. 2.1

For a particular experiment to determine the specific heat capacity of the liquid, the power supplied to the heating coil *P* is varied for different mass flow rate *m* of the liquid. The temperature of the liquid flowing into the tube is maintained at 32.4 °C and the temperature of the liquid flowing out of the tube is 35.6 °C.

The variation with *m* of *P* is shown in Fig. 2.2.

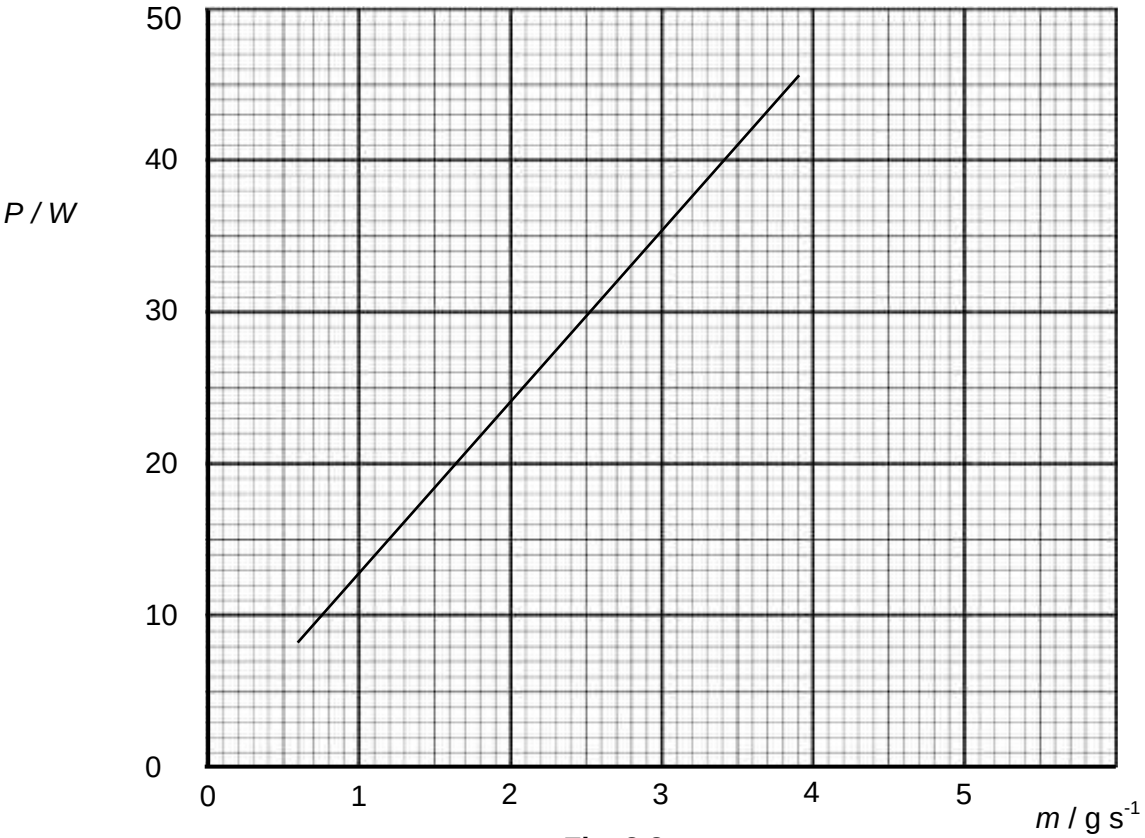


Fig. 2.2

(i) State the significance of the y-intercept.

The y-intercept is the rate at which heat is lost.

…… [1]

(ii) Use Fig. 2.2 to determine the value for the specific heat capacity in J g^{-1} °C^{-1} of the liquid. Show your working.

P = m c* (3.2) + *h

As P is plotted vs m, gradient of graph* = 3.2*c **[1]**

$$\frac{41.0-15.0}{3.50-1.20} = 3.2c \quad \textbf{[1]}$$

11.304 = 3.2*c*

***c* = 3.53 J g^{-1} C^{-1}** **[1]**

specific heat capacity = …….. J g^{-1} °C^{-1} [3]

(b) An unknown substance boils at a temperature of 120°C. The volume of 1.00 kg of element in the liquid state at 120°C is 1.10 x 10^{-3} m^3. The volume of 1.00 kg of the element in gaseous state at 120°C and atmospheric pressure 1.01 x 10^5 Pa is 2.00 m^3.

When 1.00 kg of the substance in liquid state becomes gas at 120 °C under atmospheric pressure,

(i) determine the work done against the atmosphere

W = P ΔV

= 1.01 x 10^5 x (2.00 – 1.10 x 10^{-3}) [1]

= 201.8 x 10^3 J

= 202 x 10^3 J **[1]**

work done against atmosphere = …… J [2]

(ii) determine the increase in internal energy of this mass of element during vaporisation. The specific latent heat of vaporisation of the substance at 120°C is 4.36 x 10^6 J kg^{-1}.

ΔU = Q + W

= (ml_v – 201.8 x 10^3) [1]

= (1.00 x 4.36 x 10^6 - 201.8 x 10^3)

= 4.16 x 10^6 J **[1]**

increase in internal energy = …… J [2]

(c) A fixed amount of gas is sealed in a container with a piston as shown in Fig. 2.3.

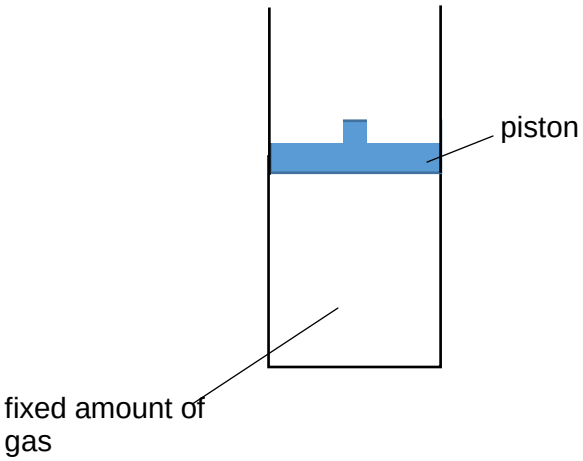


Fig. 2.3

When the gas is heated,

(i) with the piston fixed in position, explain microscopically why the pressure of the gas will increase.

As the gas is heated, the KE of the gas molecules will increase. [1]

The gas molecules will experience a larger change in momentum when they collides with the container walls thus exerting a larger force on the wall [1]
Thus causing pressure of gas to increase.
[2]

(ii) with the piston free to move, explain microscopically why the temperature of the gas may remain constant.

The gas molecules will have to do work to move the piston against atmosphere [1]

Thus losing some of the KE which they would have gained during the heating [1]
OR
Thus allowing for average KE of molecules to remain the same despite heating. [1] [2]

3 Two charged metal spheres A and B, of similar sizes are isolated in space, as shown in Fig. 3.1. Sphere A is positively charged while sphere B is negatively charged. Magnitude of charge on sphere A is larger than magnitude of charge on sphere B

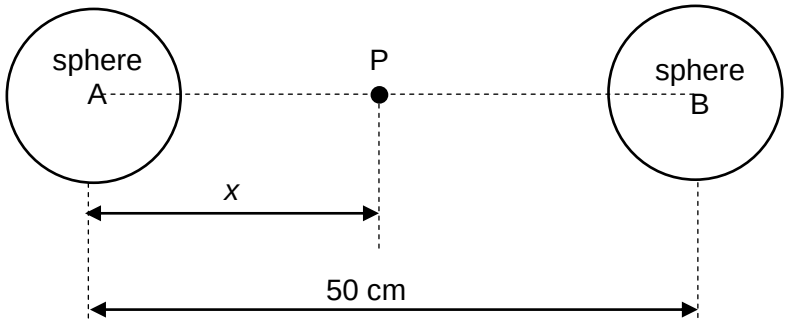


Fig. 3.1

The centres of the spheres are separated by a distance of 50 cm. Point P is at a distance *x* from the centre of the sphere A along the line joining the centres of the two spheres.

(i) Sketch the variation with *x* of the electric field strength *E* at P on Fig. 3.2 for *x* = 0 cm to *x* = 50 cm. [3]

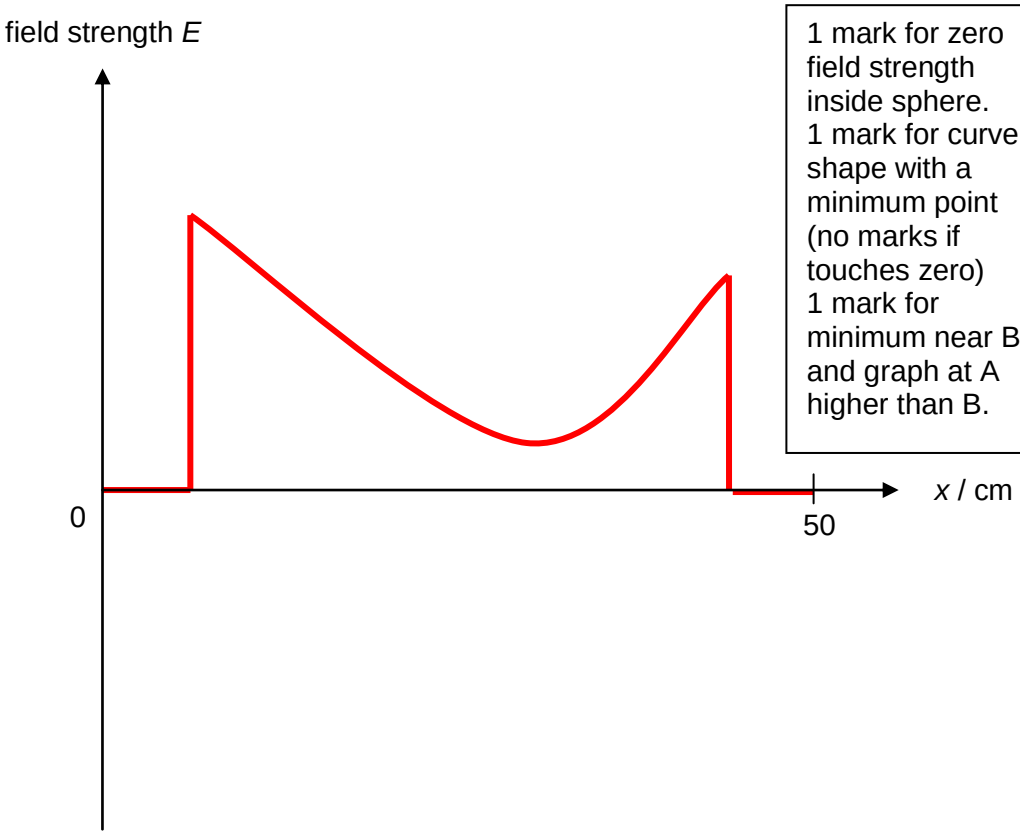


Fig. 3.2

(ii) Magnitude of charge on sphere A is 3 times that of sphere B. Determine the value of x for which point P has zero resultant electric potential.

$$\frac{Q_A}{4\pi\varepsilon_0 x} + \frac{-Q_B}{4\pi\varepsilon_0(0.50-x)} = 0$$

$$\frac{3Q_B}{4\pi\varepsilon_0 x} = \frac{Q_B}{4\pi\varepsilon_0(0.50-x)}$$ [1]

$x = 0.375$ m [1]

x = …… m [2]

(iii) State whether the point where resultant electric potential is zero must coincide with the point of minimum resultant field strength.

No. [1] Point of minimum resultant field strength is point where $\frac{dE}{dr} = 0$, which has no correlation with point where V = 0. [1]

4 A solenoid, with insulated copper wire, has current flowing in the wire as shown in Fig. 4.1.

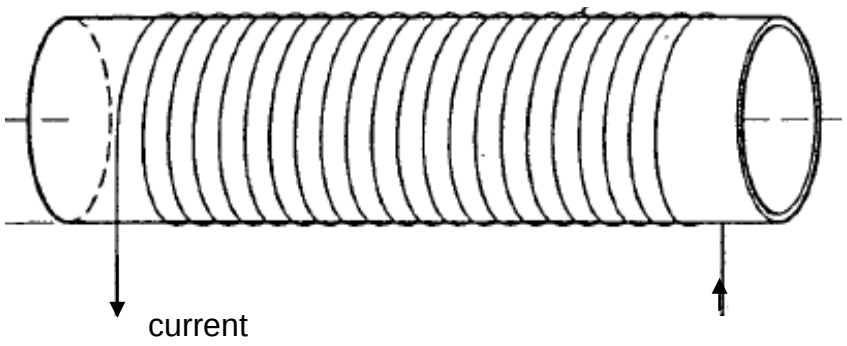


Fig. 4.1

(a) On Fig. 4.1, draw the magnetic flux pattern within and around the solenoid. [2]

Correct direction [1], equal spacing within solenoid and spaced out around solenoid [1]

(b) The solenoid is in a vacuum. An electron is injected into the magnetic field of the solenoid with a speed 3.0 x 10^6 m s^{-1} at an angle of 40° to the axis of the solenoid as shown in Fig. 4.2.

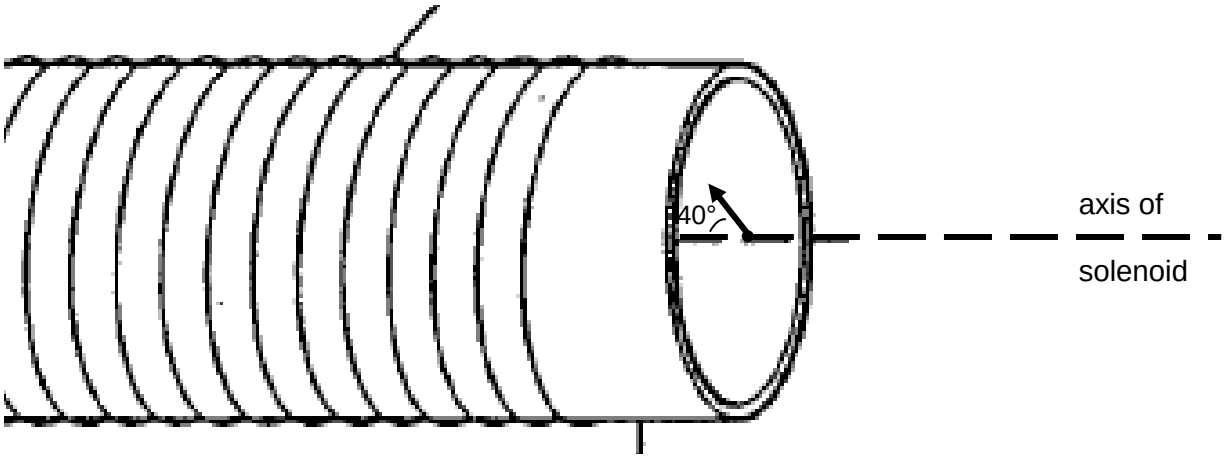


Fig. 4.2

(i) Determine the electromagnetic force acting on the electron given that the magnetic flux density of the solenoid is 2.0 mT.

$F = B_{\perp}qv$
$= 2.0 \times 10^{-3} \times 1.6 \times 10^{-19} \times 3.0 \times 10^{6} \sin 40$ [1]
$= 6.17 \times 10^{-16}$ N [1]

electromagnetic force = ……..… N [2]

(ii) By considering the components of the velocity parallel to the magnetic field and at right-angles to the magnetic field, describe and explain the path of the electron in the field.

Component of velocity normal to the axis result in circular path in the plane normal to the axis
Component of velocity along the axis of solenoid result in linear horizontal motion into the solenoid. [1]
Combined effects give rise to a helical path [1]

[2]

5 **(a)** Some data for the variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface are shown in Fig. 5.1.

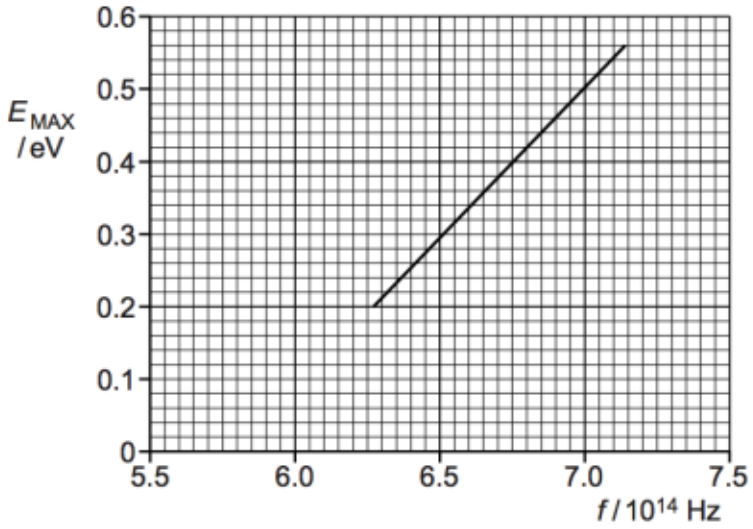


Fig. 5.1

Use Fig. 5.1 to determine

(i) the threshold frequency,

threshold frequency = 5.8 x 10^{14} ..... Hz [1]

(ii) the work function energy, in eV, of the metal surface.

$\Phi = hf_0 = 6.63 \times 10^{-34} \times 5.8 \times 10^{14}$ [M1]
$= 3.85 \times 10^{-19}$ J
$= 2.40$ eV [A1]

work function energy = ... eV [2]

(b) 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. 5.2.

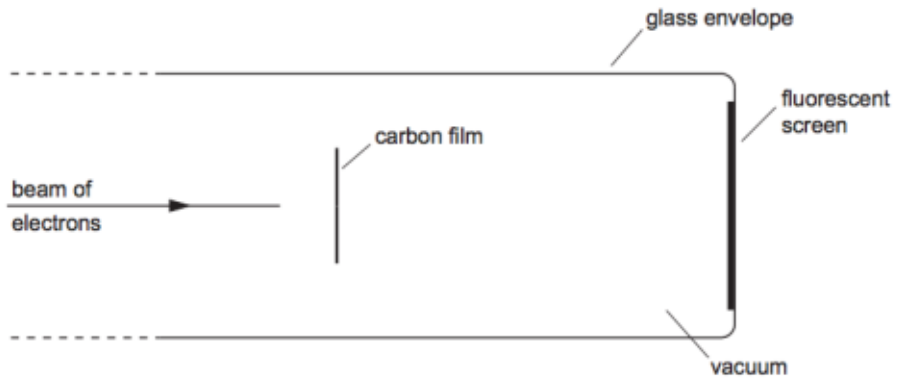


Fig. 5.2

(i) Describe briefly the pattern that is actually observed on the screen.

Concentric rings

…… [1]

(ii) The speed of the electrons is gradually increased.

State and explain what change, if any, is observed in the pattern on the screen.

……

Higher speed, higher momentum [M1]
Since $\lambda = h/p$, and λ decreases, ring diameter decreases. [A1]

…… [2]

6 Explain how does a p-n junction act as a rectifier when it is placed in a forward bias connection.

……

……

When the p-n junction is in forward bias, the n-type semiconductor is connected to the negative terminal of an e.m.f. source whereas the p-type semiconductor is connected to the positive terminal. [1]

The emf source pushes electrons in the n-side and holes in the p-side towards the junction. [1]

The depletion layer, which acts like a layer of insulation, is replenished with a fresh supply of mobile charge carriers. The depletion layer narrows, allowing the flow of current across the junction. [1]

……

…… [3]

7 **(a)** A 5.0 g sample of isotope of Bismuth-212, $^{212}_{83}\text{Bi}$, has a half-life of 60.5 min and decays to form Thallium-208. The rest mass of Bismuth-212 is 211.9913*u*.

(i) Determine the activity of radioactive Bismuth-212 after 3.5 hrs.

Mass of radioactive Bismuth after 3.5 hrs = $5.0(\frac{1}{2})^{\frac{210}{60.5}} = 0.450915$ g [1]

No. of radioactive Bismuth nuclei after 3.5 hrs =

$$\frac{0.450915\times10^{-3}}{211.9913(1.66\times10^{-27})} = 1.28135\times10^{21}$$ [1]

Activity of Bismuth nuclei after 3.5 hrs =

$$\lambda N = \frac{\ln 2}{60.5(60)}(1.28135\times10^{21}) = 2.4467\times10^{17}$$ Bq [1]

activity = ... Bq [3]

(ii) Determine the total number of Thallium-208 which is formed by the decay of Bismuth-212 within the 3.5 hours. [2]

No. of radioactive Bismuth nuclei initially =

$$\frac{5.0\times10^{-3}}{211.9913(1.66\times10^{-27})} = 1.42084\times10^{22}$$ [1]

No. of radioactive Thallium nuclei after 3.5 hrs

$= 1.42084\times10^{22} - 1.28135\times10^{21}$ [1]

$= 1.2927\times10^{22}$

number of Thallium-208 formed = ... [2]

(iii) Suggest why the actual number of Thallium-208 detected after 3.5 hours was less than the calculated answer in **(ii)**.

Thallium is probably radioactive, it will decay over time into the more stable product and therefore the actual number of radioactive Thallium is lower than the value calculated in (ii). [1]

.....

....[1]

(b) A cloud chamber enclosing air saturated with alcohol vapour is used to make visible the path of ionising radiation. When ionising radiation passes through this vapour, it causes ionisation and vapour condenses to form a 'vapour trail'. A radioactive source emitting alpha and beta particles are placed in the cloud chamber. The paths of the alpha and beta particles are traced in, as shown in Fig. 7.1

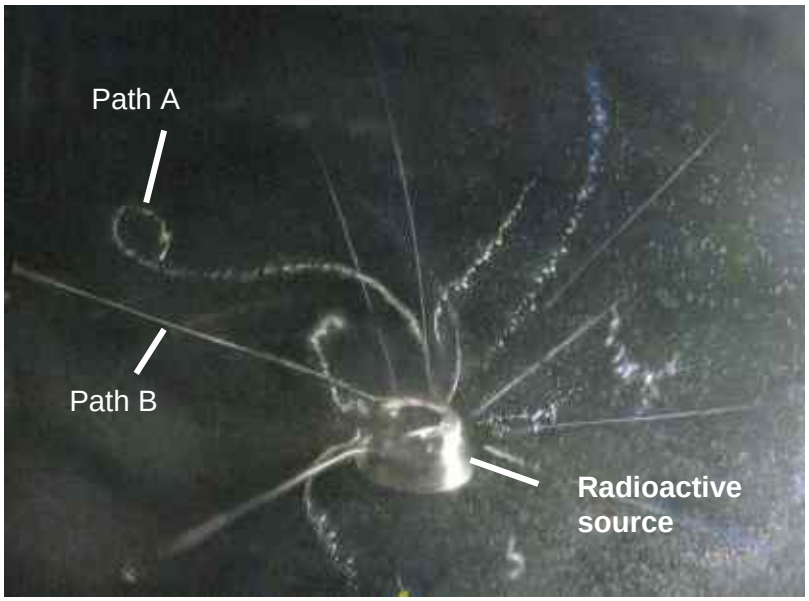


Fig. 7.1

State the type of particle that form path A and B and explain the shape of the paths.

Path A is formed by beta particles. The beta particles are small and easily deflected hence the curvy path and their ionization power is low hence the fainter traces. [1]

Path B is formed by alpha particles. The alpha particles are big and not easily deflected hence the straight path and their ionization power is high hence the distinct white line. [1] [2]

8 Ultrasonic sound waves (ultrasound) have frequencies outside the audible range of the human ear, that is, greater than about 20 kHz.

As ultrasound passes through a medium, wave energy is absorbed. The rate at which energy is absorbed by unit mass of the medium is known as *dose-rate*. The dose-rate is measured in W kg^{-1}. The total energy absorbed by unit mass of the medium is known as the *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. 8.1 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}.

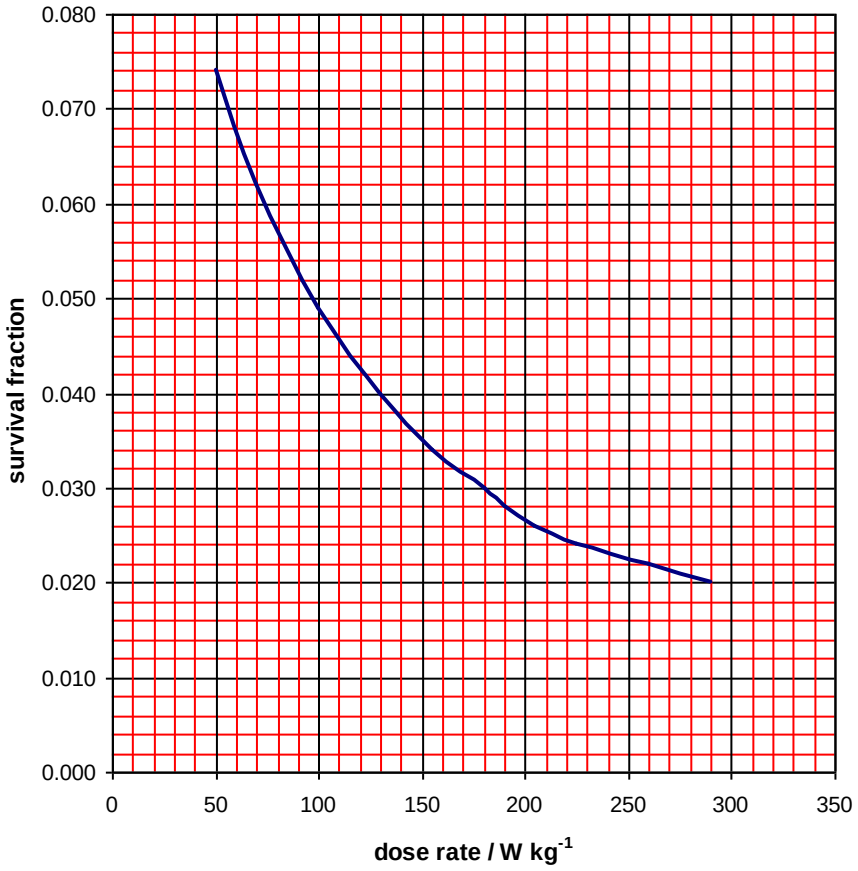


Fig. 8.1

(a) **(i)** Read off from Fig. 8.1 the survival fraction for a dose rate of 200 W kg^{-1}.

SF = ... [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]

(b) Survival fraction depends not only on dose-rate but also on absorbed dose. Fig. 8.2 shows the variation with dose rate of $\log_{10}(SF)$ for different values of absorbed dose.

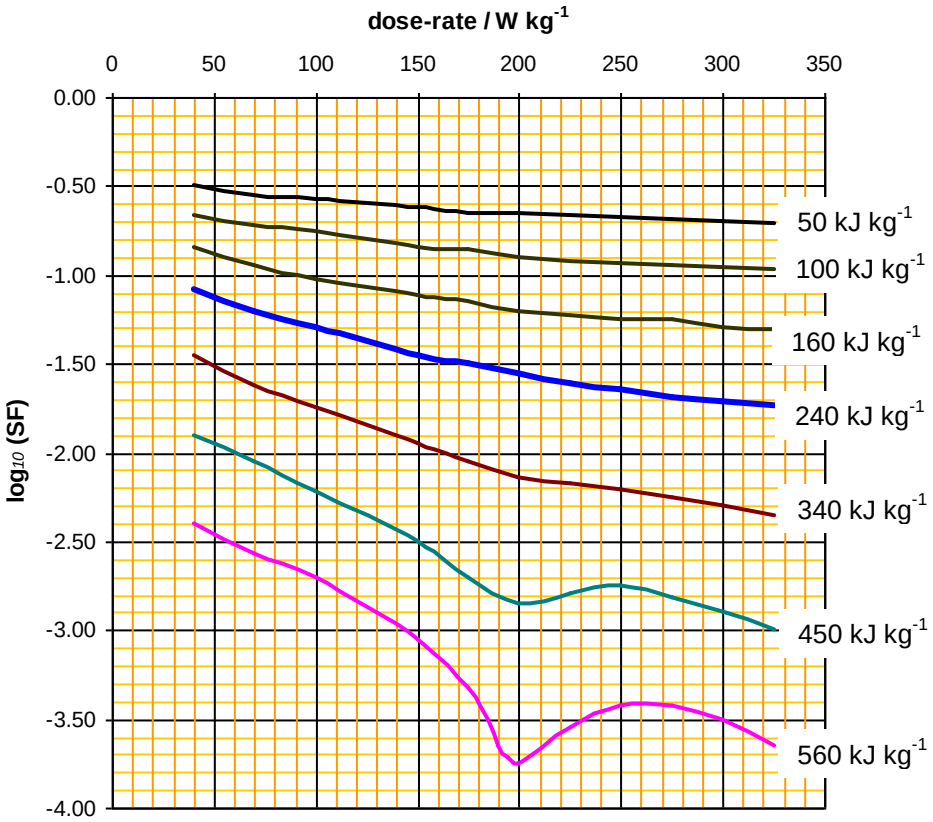


Fig. 8.2

(i) Identify the line in Fig. 8.2 that corresponds to the data given in Fig. 8.1. Label this line ***L***. [1]

(ii) By reference to Fig. 8.2, complete the table of Fig. 8.3 for a dose-rate of 200 W kg^{-1}. [1]

***Absorbed dose* / kJ kg^{-1}**	**$\log_{10}$ (*SF*)**
50	-0.65
100	-0.90
160	-1.20
240	-1.55
340	-2.13
450	
560	

Fig. 8.3

(c) Use your values in table of Fig. 8.3 to plot, on the axes of Fig. 8.4**,** a graph to show variation with absorbed dose of $\log_{10}(SF)$ for dose rate of 200 W kg^{-1}. [3]

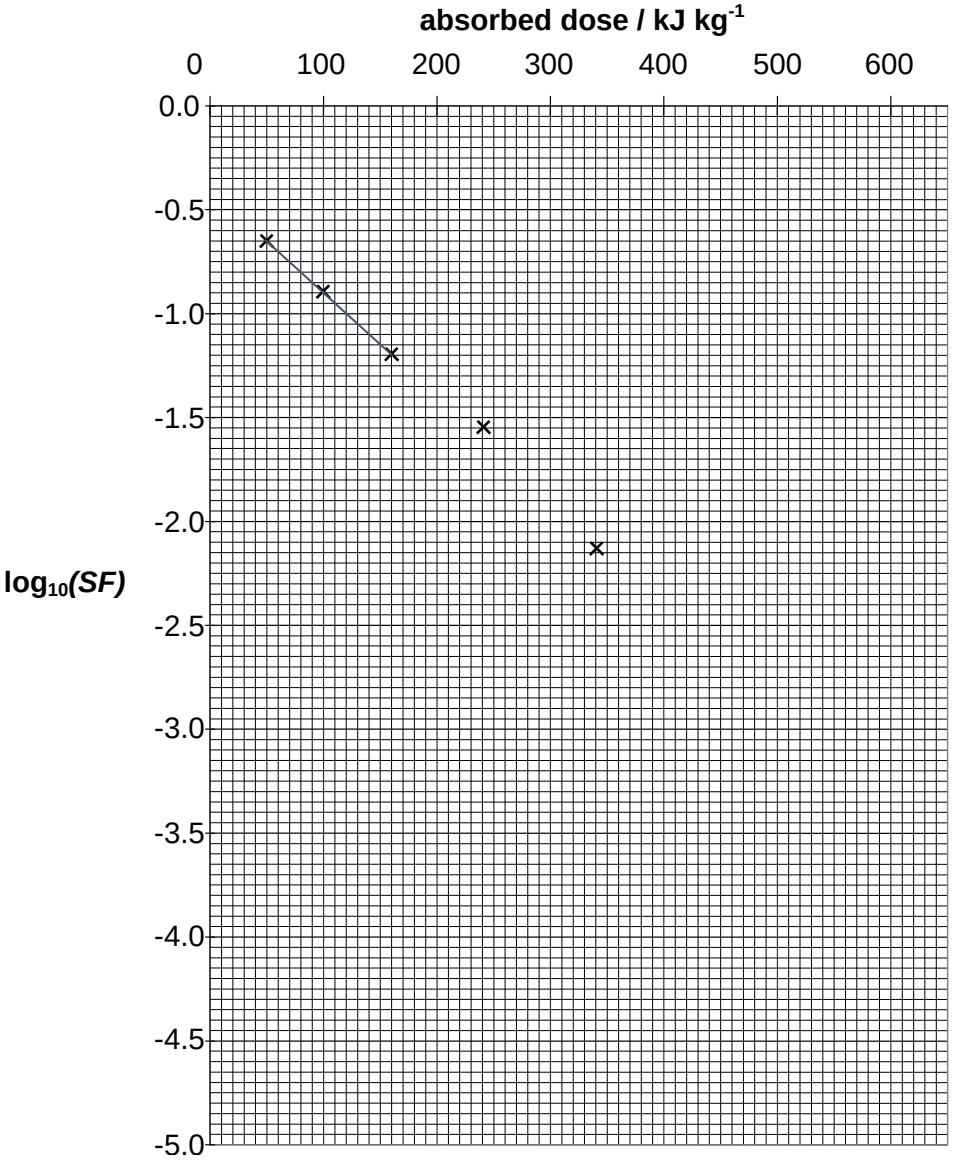


Fig. 8.4

(d) 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 that is provided for this theory by

(i) Fig. 8.2,

……

……

…… [1]

(ii) Fig. 8.4.

……

……

…… [2]

(e) The theory outlined in **(d)** suggests that the resultant survival fraction $(SF)_R$ due to the 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) Give the corresponding expression of $\log_{10}(SF)_R$ in terms of $\log_{10}(SF)_1$ and $\log_{10}(SF)_2$. You may wish to use an equation of the form $\log_{10}(ab) = \log_{10}(a) + \log_{10}(b)$. [1]

(ii) State how the graph of Fig. 8.4 may be used to determine $(SF)_R$ for an absorbed dose of 560 kJ kg^{-1}.

……

……

…… [1]

(iii) Discuss whether it is possible, by reference to your graph of Fig. 8.4**,** to determine separate values of $(SF)_1$ and $(SF)_2$ for the absorbed dose of 560 kJ kg^{-1}.

……

……

…… [2]

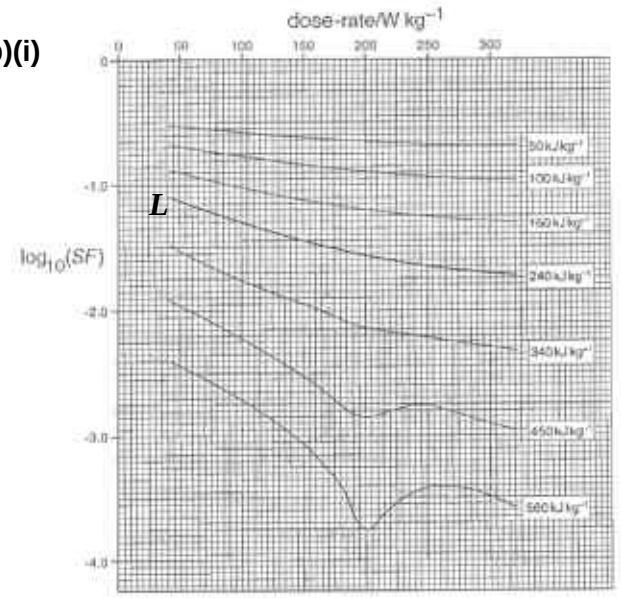
8(a)(i) *SF* = 0.0265 to 0.027 **[1]**

(ii) Exposure time $= \dfrac{\text{Absorbed dose}}{\text{Dose Rate}}$

$= \dfrac{(240 \times 10^3\ \text{J kg}^{-1})}{(200\ \text{W kg}^{-1})}$ **[1]**

= 1200 s **[1]**

(b)(i)



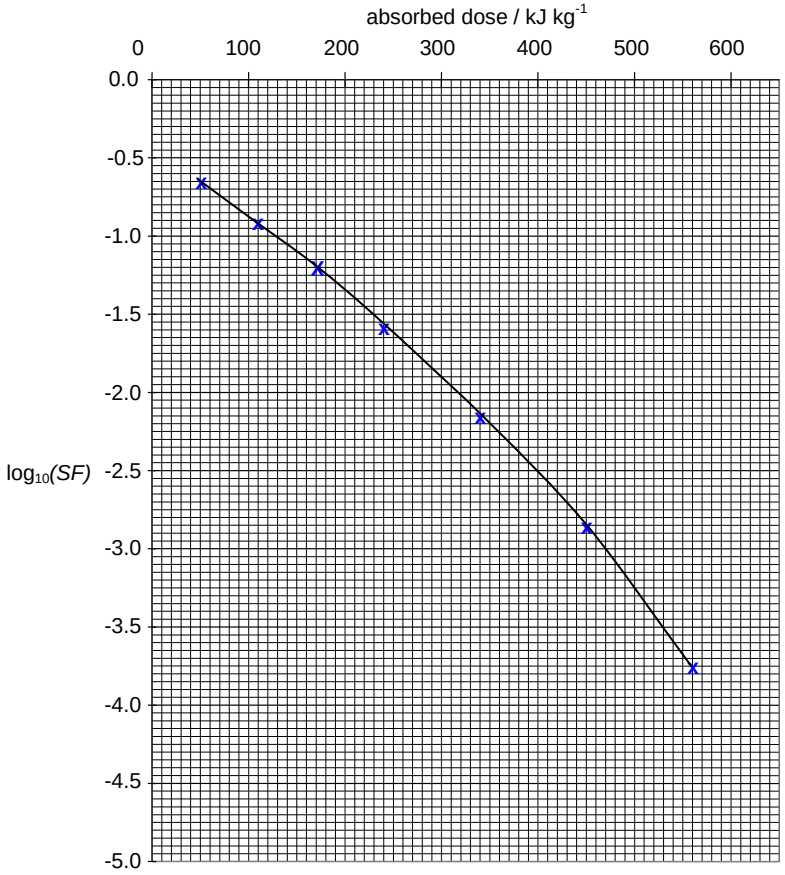
[1] – identifying the correct line

(ii) (Acceptable range)

Absorbed dose / kJ kg^{-1}	$\log_{10}$ (*SF*)
50	-0.65
100	-0.90
160	-1.20
240	-1.55
340	-2.13
450	**-2.84 to -2.86**
560	**-3.74 to -3.76**

- 1 mark for both correct

(c)



[2] –
All points correctly plotted. Each incorrect plot [-1]

[1] – Curve of best fit. A smooth curve with an initial linear portion is needed for this mark to be given.

(d)(i) From Fig 8.2 at the dose rate of 200 W kg^{-1}, there is a sudden dip in SF for higher absorbed doses greater than 340 kJ kg^{-1} **[1],** this suggests that there is another effect giving rise to cell destruction.

(ii) From Fig 8.4, we see that the initial part of the graph is linear **[1]**, after which the the graph starts to curve **[1]** suggesting a secondary effect.

(e)(i) $\log_{10} (SF)_R = \log_{10} (SF)_1 + \log_{10} (SF)_2$ **[1]**

(ii) Read off the value from the axis of $\log_{10} (SF)$ when the absorbed dose is 560 kJ kg^{-1}.

$\log (SF)_R = \log (SF)$ Let this answer be x. Then $(SF)_R = 10^x$. **[1]**

(iii) It is possible **[1]**
The linear part of the graph could be extrapolated to 560 kJ kg^{-1} to obtain the value of lg $(SF)_1$ and then lg $(SF)_2$ could then be obtained by subtracting lg $(SF)_1$ from lg (SF). **[1]**

9 A fine wire mesh has individual wires that are spaced very close together. See Fig. 9.1.

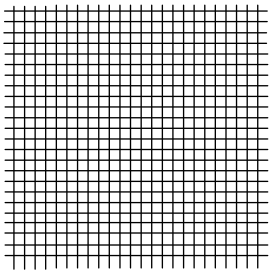


Fig. 9.1

The mesh behaves like two diffraction gratings placed at right angles to each other.

The spacing between the wires of the mesh is to be determined accurately. Design a laboratory experiment to determine the spacing between the wires using light sources of different wavelengths which are known.

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

(a) the type of light source to be used, giving a reason for your choice,
(b) the procedure to be followed and the measurements that would be taken,
(c) how the spacing between the wires would be deduced,
(d) any important precautions you would take to improve accuracy of your experiment,
(e) any safety precautions you may take.

Diagram

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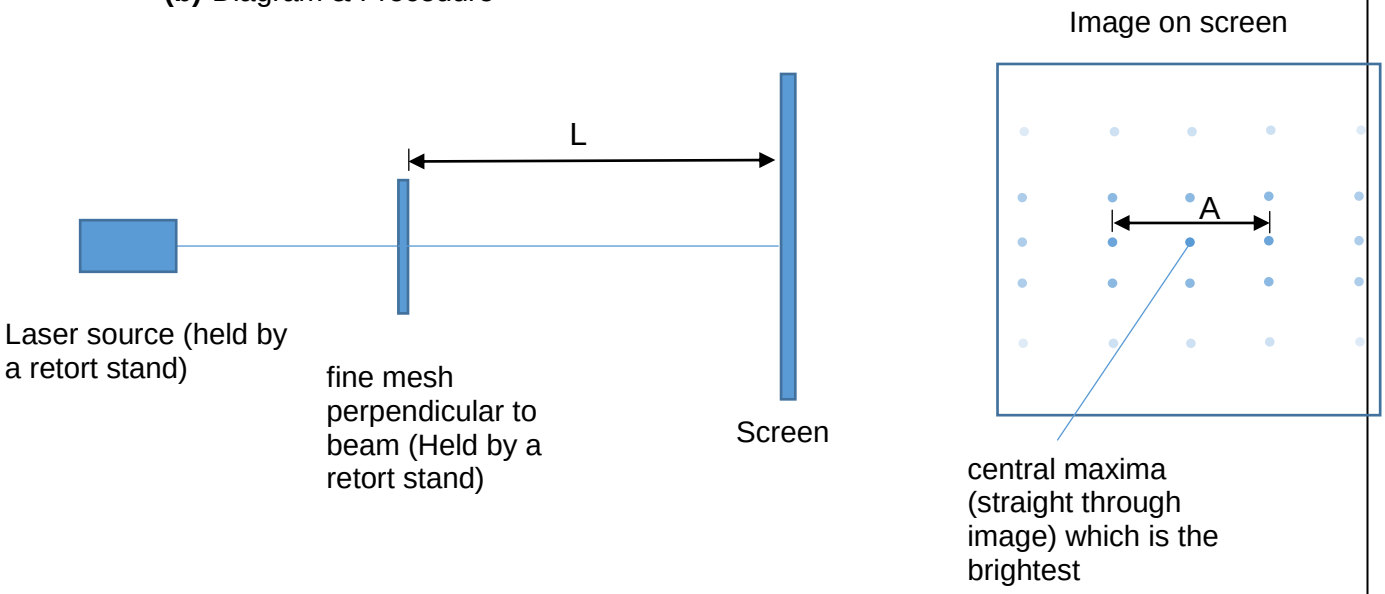
Suggested Solution

(a) The type of light source to be used must be a laser to ensure that the source is coherent and an observable interference pattern due to the diffraction grating can be formed.

(b) Diagram & Procedure



1. Set-up the experiment as shown.
2. Record the wavelength of the laser source as λ and switch the beam on.
3. This is followed by measuring the vertical distances between the central maxima and the first order maxima
4. Measure the distance of mesh to the screen with a metre rule and record as (L).
5. With laser source on, a diffraction pattern will be seen on the screen.
6. Measure the distance between the two first order maxima (A) with a metre-rule (as seen in Figure above.)
7. Calculate the angle θ by using the formula $\tan\theta = A / (2L)$
8. Repeat steps 2-7 for 5 more sets of data with different λ.

(c) Data analysis

Using the equation $d\sin\theta = n\lambda$ (where n = 1 and d is the spacing between the wires.

Rearranging, $\lambda = d\sin\theta$,

By plotting a graph of λ vs sin θ, a straight line would be obtained with gradient = d

Determine the gradient to determine d.

(d) Additional details to improve accuracy of experiment.

The choice of the first order was because the higher order maxima will be of a lower intensity and will be harder to locate on the screen.

Ensure that the beam of laser and the fine mesh is mutually perpendicular by using a metre rule to measure the horizontal distances and vertical distances between the central maxima and the first order maximas. Adjust the wire mesh to ensure that the distances are the same.

(e) Safety precautions

As the laser is highly intense, googles should be worn and also one should avoid looking directly into the laser.

Mark Scheme

A1 Diagram of arrangement (light source/mesh/screen or collimator/mesh/telescope) [1]

A2 Fringes or dots shown on screen. May be shown on diagram. [1]

A3 Use of laser or single slit (and lens) in collimator [1]

A4 Some discussion of coherence of the source [1]

B1 Measurements: distance from mesh to screen and separation between fringes [1] OR measure an angle from the spectrometer table

B2 n = 1; find separation between central fringe and first bright fringe [1] OR measure angle between central bright beam and first order beam using scale on table (Fixing of n as a fixed value)

B3 Use of $d\sin\theta=n\lambda$ to find d. n must be clearly identified [1]

B4 Plotting of a graph with d as gradient or 1/d as gradient [1]

C Any safety precaution [1]
e.g. use goggles/do not look directly into laser beam/cover over sodium lamp do not touch the bulb
D Any good/further detail [3]

Examples of creditworthy points might be:

- Take readings with mesh in different positions to average d
- Sketch/suggestion of two-dimensional array of dots on screen Laser + mesh + screen all at same height
- Distance of mesh to screen of the order of 1 m to 4 m (laser method)
- Measure 2θ and divide by two to reduce uncertainty in θ OR distance between two 1st order maxima, divided by two to reduce uncertainty in calculating θ
- Repeat experiment with 2nd order (3rd order etc.) beams Detail relating to setup/use of spectrometer Allow other valid points.
- Ensuring that the wire mesh is perpendicular to the beam of light.
- Usage of higher order (n=2) leading to lower intensity of maxima detected as part of consideration.
- Use of a dark room to minimise light pollution and allow for more accurate location of the maximas.

SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

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PHYSICS 9646/03

Preliminary Examination **19th Sept 2016**
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 **A**
Answer **all** questions.

Section **B**
Answer any **two** 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	/ 9
Q2	/ 5
Q3	/ 5
Q4	/ 5
Q5	/ 5
Q6	/ 5
Q7	/ 6
Q8	/ 20
Q9	/ 20
Q10	/ 20
Total marks	/ 80

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}
		=	$(1/(36\ \pi)) \times 10^{-9}$ 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, $p = \rho gh$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_0 \sin \omega t$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$

$= \pm\omega\sqrt{x_0^2 - x^2}$

mean kinetic energy of a molecule $E = \frac{3}{2}kT$

of an ideal gas

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = Q/4\pi\varepsilon_0 r$

alternating current/ voltage, $x = x_0 \sin \omega t$

transmission coefficient, $T \alpha \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided

1 A ball falls off a building that is (70 ± 1) m high. It takes 3.78 s to hit the ground. It is estimated that there is a percentage uncertainty of ± 8% in measuring this time interval.

(a) Determine the acceleration of free fall of the ball to an appropriate number of significant figures.

$s = \frac{1}{2}gt^2$

$g = \frac{2s}{t^2} = \frac{2(70.0)}{3.78^2}$ [M1]

$= 9.798$ m s^{-2}

$\frac{\Delta g}{g} = \frac{\Delta s}{s} + 2\frac{\Delta t}{t} = \frac{1}{70} + 2(0.08)$ [M1]

$\Delta g = 0.174 \times 9.798 = 1.708 = 2$ [M1 for rounding up Δg correctly]

g = (10 ± 2) m s^{-2} [A1 for rounding off g correctly]

acceleration = …… ± …….. m s^{-2} [4]

(b) The variation with time t of the velocity v of another ball falling through air is shown in Fig. 1.1.

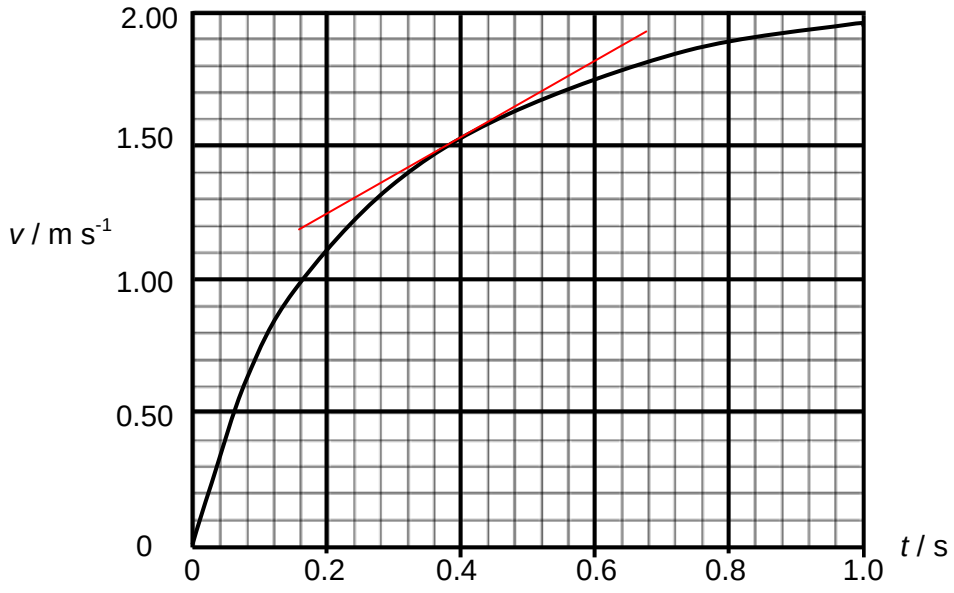


Fig. 1.1

(i) Using Fig. 1.1, describe how the speed of the ball varies with time.

…… Speed increases at a decreasing rate. [B1] ……

…… [1]

(ii) Determine the acceleration of the ball falling through air at time t = 0.4 s.

acceleration = gradient of v-t graph

$$= \frac{1.95 - 1.20}{0.68 - 0.16}$$ [M1]

= 1.44 m s^{-2} [A1]

Accepted 1.21 ~ 1.67 m s^{-2}.

acceleration = ... m s^{-2} [2]

(iii) The mass of the ball is 25 g. Determine the resistive force acting on the ball at time t = 0.4 s.

$F_{net} = ma$

$W - F_R = ma$

$F_R = W - ma = 0.025\ (9.81 - 1.44)$ [M1]

$= 0.209$ N [A1]

resistive force = ... N [2]

2 Coherent light is incident normally on a double slit, as shown in Fig. 2.1.

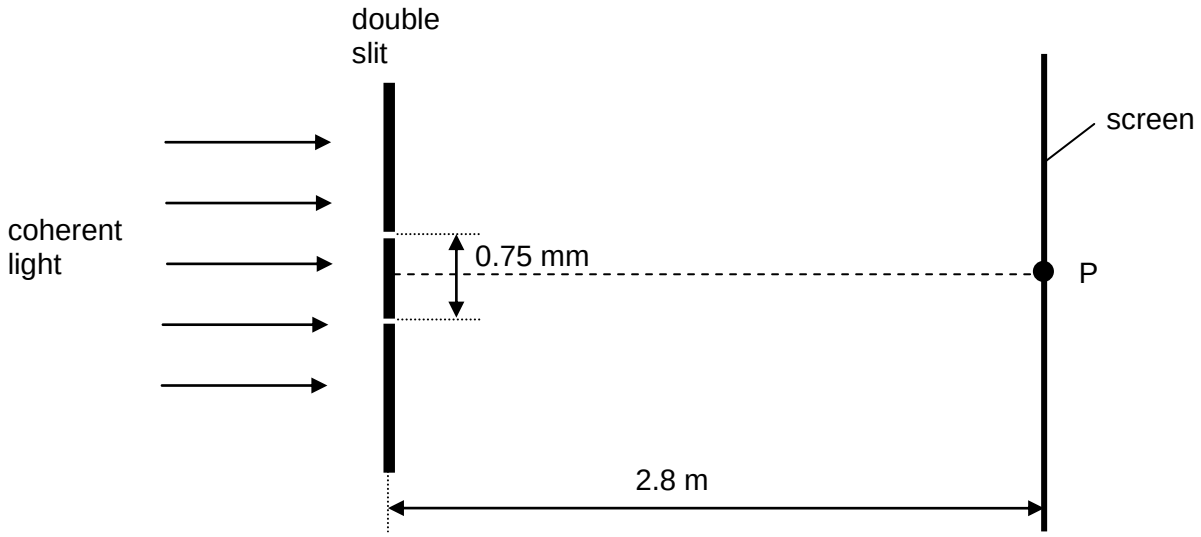


Fig. 2.1

The separation of the slits in the double slit arrangement is 0.75 mm.

A screen is placed parallel to, and at a distance of 2.8 m, from the double slit. P is a point on the screen that is equidistant from the two slits.

The interference pattern formed on the screen has a fringe separation of 1.2 mm.

(i) Calculate the wavelength, in nm, of the coherent light.

$$x = \frac{\lambda D}{a}$$

$$\lambda = \frac{xa}{D}$$

$$= \frac{(1.2\times10^{-3})(0.75\times10^{-3})}{2.8} \text{ [1]}$$

$$= 321 \text{ nm [1]}$$

wavelength = …….. nm [2]

(ii) The intensity of the light on one of the slits is reduced to 25% of the intensity of light from the other slit.

Determine, for the bright fringe at P and the dark fringe closest to point P, the ratio $\frac{\text{amplitude of light at the bright fringe}}{\text{amplitude of light at the dark fringe}}$.

Intensity α Amplitude^2

$\frac{I_1}{I_2} = (\frac{A_1}{A_2})^2$

$A_1 = \sqrt{0.25}A_2$ [1]

Resultant A at bright fringe=$A_1 + A_2 = (\sqrt{0.25} + 1)A_2$

Resultant A at dark fringe=$A_2 - A_1 = (1 - \sqrt{0.25})A_2$ [1 for both expressions]

$\frac{\text{amplitude of light at the bright fringe}}{\text{amplitude of light at the dark fringe}}$

$= \frac{\sqrt{0.25} + 1}{1 - \sqrt{0.25}}$

$= 3.0$ [1]

ratio = …… [3]

3 In order to investigate the value of the internal resistance of a battery r, a student sets up a circuit as shown in Fig. 3.1.

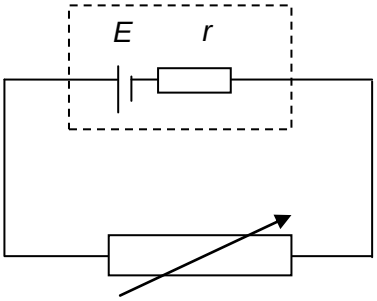


Fig. 3.1

The power dissipated in the variable resistor is P_v. The variation of P_v with resistance R of the variable resistor is shown in Fig 3.2.

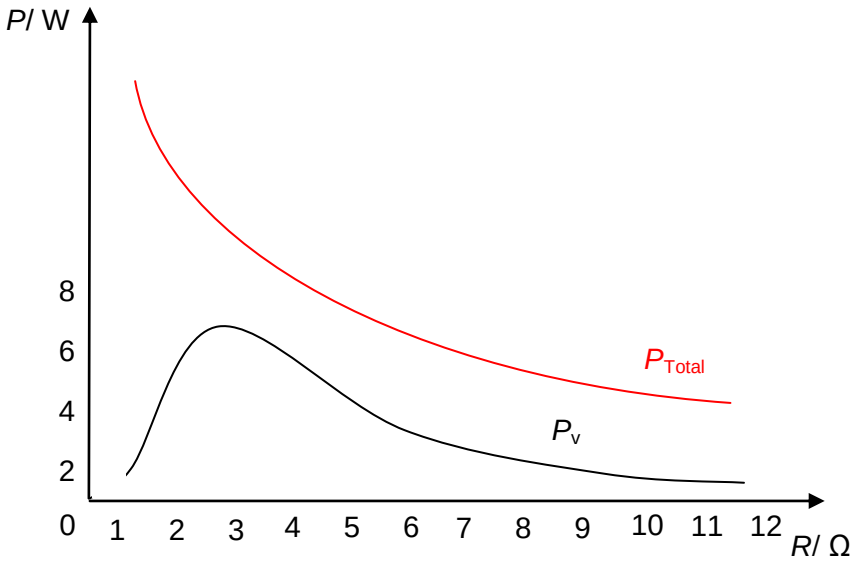


Fig. 3.2

(a) Explain how the student can deduce that the value of the internal resistance of the circuit, r is 3 Ω.

(By Maximum Power Theorem), the power dissipated by the load (variable resistor) is the maximum when the resistance of the load (variable resistor) is equal to the resistance of the internal resistance. [1]

[1]

(b) For resistance R = 3 Ω, calculate the efficiency of transfer of power from the supply to the variable resistor.

$$\eta = \frac{P_{out}}{P_{gen}} = \frac{IV}{IE} = \frac{V}{E} = \frac{IR}{I(R+r)} = \frac{R}{R+r} = \frac{3}{3+3} = 50\%$$

efficiency = ……% [2]

(c) Sketch, without any further calculations, the variation of the total power with resistance of the variable resistor in Fig. 3.2. Label the graph as $P_{\mathbf{Total}}$. [1]

(d) A student is asked to design a circuit that provides maximum efficiency of energy transfer to a component. Thus, he correctly selected a battery that has an internal resistance that is much lower than the resistance of the load.

Explain the reason for his choice.

From part (b), since $\eta = \frac{R}{R+r}$, a smaller value of internal resistance relative to the load's resistance would mean that there is lower percentage of the total power dissipated in the internal resistance. [1] Hence, that would increase the efficiency of the energy transfer to the load.

[1]

4 A simple iron core transformer is shown in Fig 4.1.

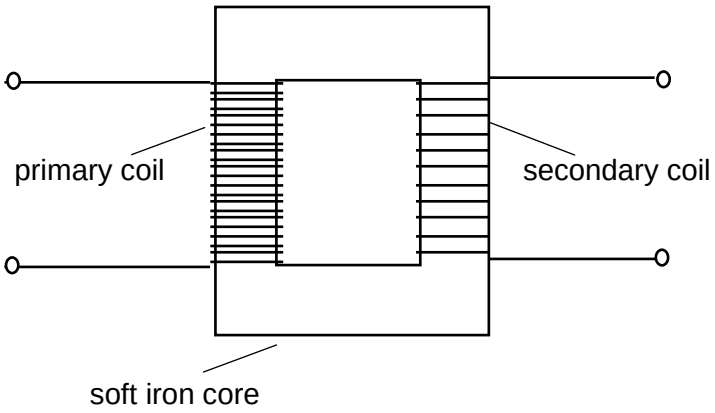


Fig. 4.1

(a) State Faraday's law of electromagnetic induction.

The induced e.m.f is directly proportional to the rate of change of magnetic flux linkage. [2]

[2]

(b) Use Faraday's law to explain whether the current in the primary coil is in phase with the e.m.f induced in the secondary coil.

In the primary coil, magnetic flux produced in coil is in phase with current [1]

As the magnetic flux linking primary coil to secondary coil is changing, there is an induced e.m.f in secondary coil. [1]

The flux and rate of change in flux are not in phase. [1]

[3]

5 An X-ray tube operates with a p.d across the tube of 90 kV. Fig. 5.1 shows the X-ray spectrum emitted.

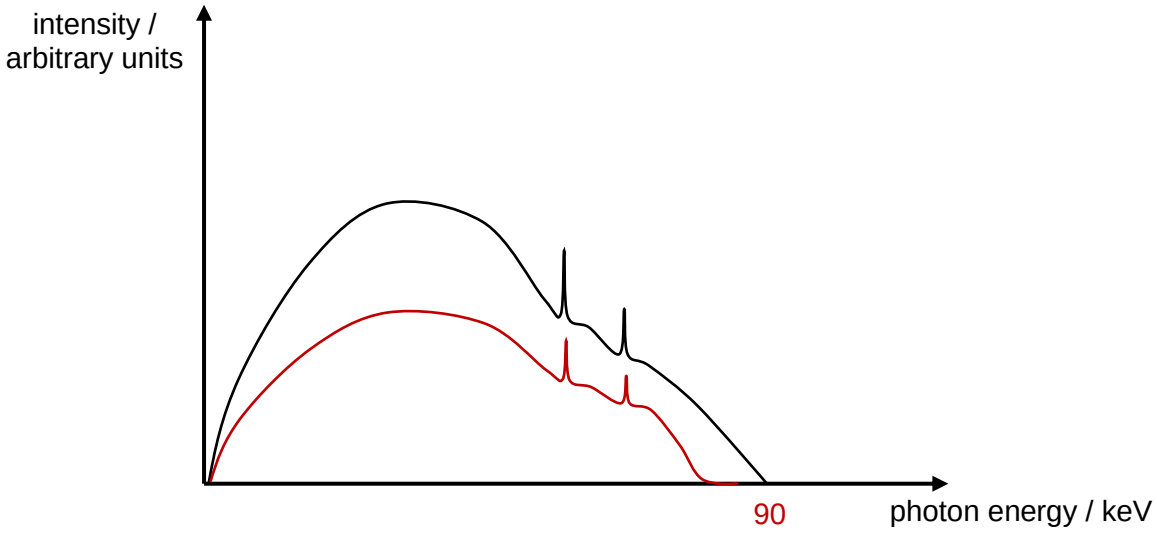


Fig. 5.1

(a) State the maximum photon energy detected in Fig.5.1.

maximum photon energy = …….. keV [1]

(b) Explain why the spectrum has sharp spikes at specific photon energies.

The photons of specific energies arises because

Incident electrons on target metal are able to knock out the electrons deep within the target metal causing a vacancy to occur at K shell. [1]

When electrons from higher energy levels de-excite (to fill in the vacancies), the photons emitted are of specific energies equal to the energy gap between the two levels. [1] [2]

(c) Sketch in Fig. 5.1 the expected X-ray spectrum when the p.d across the tube is reduced to 80 kV. [2]

New graph must have
Bremsstrahlung radiation lower than original graph [1]
Peaks occurring at same specific energy [1]
Minimum photon energy must be starting at the same position while max photon energy should be lower.

For Examiner's Use

6 **(a)** Describe how band theory is used to explain the difference between the conduction properties of insulators and **intrinsic** semiconductors.

For insulators, there is a **large energy gap** between empty conduction band and completely filled valence band at 0 K.
At room termperature (≈ 300 K), the **thermal energy possessed** by the valence electrons is **much smaller than** the **energy gap**. **Very few electrons have sufficient energy to 'jump' the energy gap to exist in the conduction band**. Therefore insulators are unable to conduct electricity.

For intrinsic semiconductors, there is a **small energy gap** between empty conduction band and completely filled valence band at 0 K.
At room temperature (≈ 300 K), the **thermal energy possessed** by the valence electrons is **sufficient for them to 'jump' the small energy gap** to exist in the conduction band.
When the valence electrons move into the conduction band, they **leave behind empty states called 'holes'**. **Both** the **electrons in the conduction band and holes in the valence band contribute to** the **conduction** of electricity.

…… [3]

(b) Explain the use of doping to change the conduction properties of semiconductors.

Small amounts of dopants are added to a semiconductor to increase the no. of charge carriers and hence electrical conductivity of the intrinsic semiconductor, resulting in extrinsic semiconductors.

EITHER
When a group 4 semiconductor is doped with a group 3 atom, an **acceptor level** is created **just above the valence band**. **Valence electrons can easily jump to the acceptor level**, leaving behind holes in the valence band. [B1] Hence there is an **increase in no. of (conduction) holes** and hence semiconductor's **conductivity/** majority charge carrier: holes. [B1]

OR
When a group 5 atom is added instead, a **donor level** is created **just below the conduction band**. The **electrons in the donor level can easily jump into the conduction band**. Hence there is an **increase in no. of (conduction) electrons** and semiconductor's **conductivity/** majority charge carriers: electrons. [B1]

…… [2]

7 When beryllium-9 is bombarded with α-particle of energy *E*, carbon atoms and neutrons are produced, together with a very penetrating γ-radiation. The nuclear reaction is

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{12}_{6}\text{C} + ^{1}_{0}\text{n} + \gamma$$

The binding energy per nucleon of the nuclei are

$^{9}_{4}\text{Be}$, 6.462758 MeV

$^{4}_{2}\text{He}$, 7.073915 MeV

$^{12}_{6}\text{C}$, 7.680144 MeV

(i) Define the following terms:

1. *nuclear fusion.*

Nuclear fusion is the process of the building up of a larger nucleus from two smaller nuclei [1]

[1]

2. *binding energy per nucleon*.

Amount of energy needed to separate nucleus into individual nucleons infinitely far apart divided by total number of nucleons. [1]

(ii) Determine the energy released in this reaction.

Energy released

$= BE_{product} - BE_{reactant}$

$=12(7.680144)-[9(6.462758)+4(7.073915)]$MeV [1]

$= 5.701246$ MeV [1]

$= 9.1219936 \times 10^{-13}$ J [1]

energy released = …… J [3]

(iii) The total kinetic energy of the carbon atom, neutron and the energy of radiation for each reaction is found to be more than the answer in **(ii)**. Suggest a reason for this difference.

As the total kinetic energy of the carbon atom, particle X and the energy of radiation is more than the energy released in the reaction, there must be an initial amount of energy that the reactants possess for there to be conservation of energy. **This should have come from the initial kinetic energy of the alpha particle and/or beryllium.** [1]

Section B

Answer **two** questions from this Section in the spaces provided

8 A stationary radioactive nucleus polonium $^{210}_{84}Po$ undergoes α-decay process. In the α-decay process, a daughter nucleus X is formed with the simultaneous emission of an α-particle of energy 0.2 MeV and a photon of energy 6.1 MeV.

Data of the masses of the particles in the decay process are given in Fig. 8.1.

	mass / u
$^{210}_{84}Po$	209.98285
X	205.97447
α-particle	4.00151

Fig. 8.1

(a) **(i)** State the composition of the daughter nucleus X.

84-2 = 82 protons
210-4 = 206 nucleons, 206-82 = 124 neutrons
82 protons and 124 neutrons [1]

(ii) The mass of the polonium (Po) nucleus is greater than the combined mass of the α-particle and X. Use a conservation law to explain qualitatively how this decay is possible.

mass-energy is conserved [1]
difference in mass 'changed' into a form of kinetic energy of the products and γ-radiation photons / e.m. radiation [1]

(iii) Show that the momentum of the daughter nucleus X is 1.1 x 10^{-19} N s. [3]

mass-energy difference = (209.98285 - 205.97447 - 4.00151) x 1.66 x 10^{-27} x $(3.0 \times 10^8)^2$ [1]
= 1.026 x 10^{-12} J
KE of X = 1.026 x 10^{-12} – (0.2 + 6.1) x 10^6 x 1.6 x10^{-19} [1]
= 1.80 x10^{-14}J

$$Momentum\ of\ X = \sqrt{2mKE} = \sqrt{2(205.97447) \times 1.66 \times 10^{-27} \times 1.80\ x10^{-14}} \quad [1]$$

$$= 1.11 \times 10^{-19}\ \text{Ns}$$

(b) (i) Explain what is meant by a *photon*.

Photon is a <u>packet of electromagnetic radiation</u> / <u>packet</u> of <u>light energy</u>

(ii) Determine the wavelength of the photon.

$$E = hf = h\frac{c}{\lambda} \Rightarrow (6.1\times10^{6}\times1.6\times10^{-19}) = (6.63\times10^{-34})\frac{3\times10^{8}}{\lambda} \text{ [1]}$$

$$\Rightarrow \lambda = 2.04\times10^{-13}\,\text{m} \quad \text{[1]}$$

wavelength = ……..… m [2]

(iii) Show the linear momentum of the photon is 3.25 x 10^{-21} N s. [1]

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{2.04\times10^{-13}} = 3.25\times10^{-21}\,\text{Ns}$$

(iv) Suggest why the photons emitted from the decay process of a large sample of radioactive particles exert a pressure on a metal surface when these photons are incident on it.

Photons can be <u>absorbed or reflected from the metal surface and hence they experience a change of momentum with time</u>, according to Newton's 2nd law of motion, there is a <u>force acting on these photons</u>. [1]
By Newton's 3rd law of motion, there will be <u>an equal and opposite force by the photons on the metal surface.</u> [1]
<u>Force per unit area is pressure</u>, so the incident photons would exert a pressure on the surface, known as radiation pressure.

[2]

(c) An illustration of another α-decay process is as shown in Fig. 8.2.

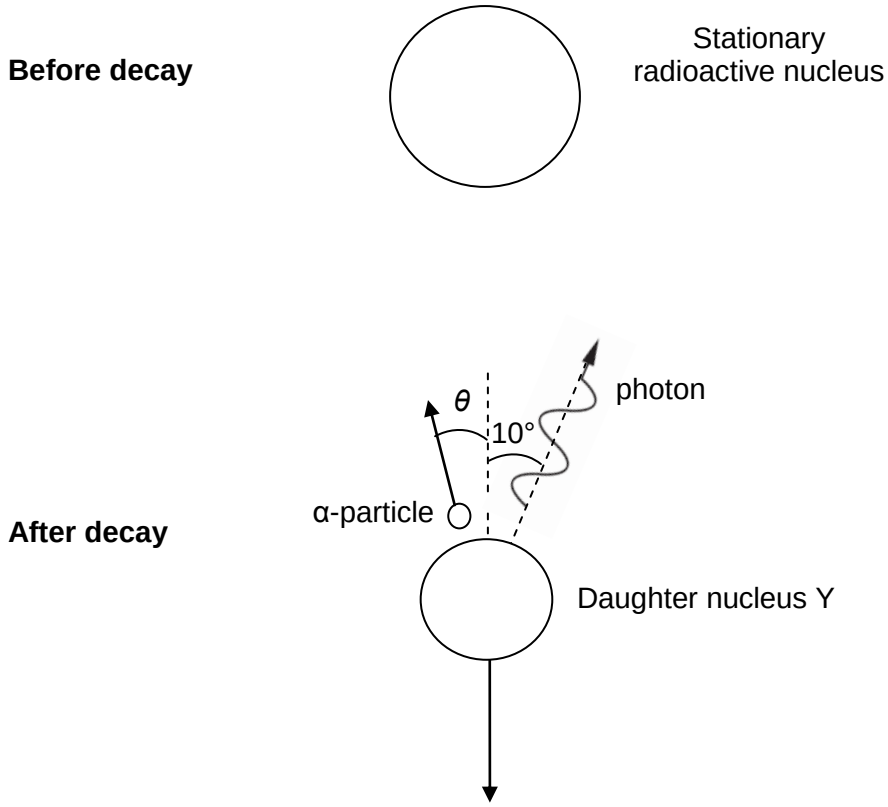


Fig. 8.2

After the emission, the daughter nucleus Y, α-particle and photon are emitted in the directions as shown in Fig. 8.2.

(i) State the principle of conservation of linear momentum.

Principle of conservation of linear momentum states that the net momentum of a system remains constant when no external resultant force acts on the system.

[2]

(ii) Explain why momentum is conserved during this emission.

There is no resultant external force on the system consisting of the daughter nucleus Y, α-particle and photon during the radioactive decay. [1]

[1]

(iii) Momentum is a vector quantity and can be resolved into perpendicular components.

After the decay, the momentum of the daughter nucleus Y is 1.11 x 10^{-19} N s and the momentum of the photon is 3.25 x 10^{-21} N s.

Calculate the angle θ as shown in Fig. 8.2.

By COLM,

Horizontally, $\rho_\alpha \sin\theta = \rho_{photon} \sin 10°$ [1]

Vertically, $\rho_\alpha \cos\theta + \rho_{photon} \cos 10° = \rho_Y$ [1]

$$\tan\theta = \frac{\rho_{photon} \sin 10°}{\rho_Y - \rho_{photon} \cos 10°}$$

Solving,

$$\theta = \tan^{-1}\left[\frac{\rho_{photon} \sin 10°}{\rho_Y - \rho_{photon} \cos 10°}\right]$$

$$= \tan^{-1}\left[\frac{3.25\times10^{-21} \sin 10°}{1.11\times10^{-19} - 3.25\times10^{-21} \cos 10°}\right]$$

$$= 0.3°$$ [1]

angle θ = ……..… ° [3]

(iv) If the daughter nucleus Y is stationary after the decay, deduce and explain the directions of motion of the α-particle and the photon.

……

As the total initial momentum is zero, by COLM, the total momentum of the daughter nucleus Y, α-particle and the photon will be zero. [1]
Since Y remains stationary, the α-particle and the photon must move off in opposite directions with the same momentum [1]
to ensure the total momentum of the system remains zero

……[2]

9 **(a)** Define *gravitational potential energy*.

Gravitational potential energy possessed by a mass at a point is the work done by an external force in bringing the mass from infinity to that point. [1]

(b) Explain why is gravitational potential at a point is negative.

Gravitation force are attractive in nature. As the mass is brought from infinity to that point at a constant speed, there needs to be an external force applied in the opposite direction to the gravitational force. [1]

Hence, the work done by the external force on the mass is negative since the direction of the external force and the displacement of the mass are opposite in direction. [1]

(c) The Earth may be considered to be a uniform sphere with its mass of 5.98×10^{24} kg concentrated at its centre.

A satellite of mass 850 kg rotates in a uniform circular motion about the axis of the Earth with an orbital radius *R* with a gravitational potential energy of -5.0×10^{10} J.

(i) Calculate the value of *R*.

Since GPE = -GMm/R

$5 \times 10^{10} = (6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 850) / R$

$R = 6.78 \times 10^{6}$ m

R = ……m [1]

(ii) Show that, for a satellite in orbit, the ratio of the gravitational potential energy of the satellite to its total energy is equal to 2. [3]

Since gravitational force provides the centripetal force, [1]

$GMm/R^2 = mv^2/R$

$½\ mv^2 = GMm/2R$ [1]

$$\frac{GPE}{TE} = \frac{\frac{-GMm}{R}}{\frac{GMm}{2R} + \frac{-GMm}{R}} \quad [1]$$

$$= \frac{\frac{-GMm}{R}}{\frac{-GMm}{2R}} = 2$$

(iii) Hence, or otherwise, calculate the total energy possessed by the satellite as it moves in this orbit.

Since GPE = - 5.0 x 10^{10} J, TE = -2.5 x 10^{10} J (since ratio is 2)

total energy = ……..J [1]

(iv) Determine quantitatively whether the satellite could be in geostationary orbit. [3]

Since KE = 2.5 x 10^{10}, v = 7.67 x 10^3 m s^{-1} [1]

$$T = \frac{2\pi r}{v} = \frac{2\pi(6.78x10^6)}{7.67x10^3} = 5.55x10^3 s = 1.54 \text{ hrs} \quad [1]$$

For the satellite to be geostationary, it must have a period of **<u>24 hours</u>** (same as the period of the Earth). Hence, this is **<u>not a geostationary orbit</u>**. [1]

(v) After certain time, the satellite moved into a circular new orbit. In this new orbit, it possessed a new kinetic energy of 8.0×10^{10} J.

1. Calculate the radius of this new orbit.

Since KE = GMm/2R

$8 \times 10^{10} = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 850 / 2R$

$R = 2.11 \times 10^{6}$ m

radius of new orbit = ……..……..m [1]

2. Explain why many satellites eventually 'burn up' in the Earth's atmosphere.

As the satellite loses energy due to work done against atmospheric friction, its TE will be more negative [1] Thus, the satellite is moving closer to Earth. When that happens, the KE will increase. [1] As the satellite moves faster, it will encounter more atmospheric friction and hence more work is done to overcome atmospheric friction. [1] This means there will increasing amount of thermal energy which will cause the satellite to burn up.

[2]

(d) The planet Jupiter has a mass of 1.89×10^{27} kg. A rock, initially at rest a long distance from Jupiter, travels towards Jupiter and reaches the surface with a speed of 6.0×10^{4} m s^{-1}.

(i) Show that the radius of Jupiter is 7.0×10^{7} m. [2]

By Conservation of Energy,

$KE_i + PE_i = KE_f + PE_f$

$0 + 0 = ½ mv^2 + (-GMm/R)$ [1]

$R = (6.67 \times 10^{-11} \times 1.89 \times 10^{27}) / ½ (6 \times 10^{4})^2$ [1]
$= 7.0 \times 10^{7}$ m

(ii) Helium-4 may be assumed as an ideal gas.

Calculate the temperature of helium-4 gas at which the r.m.s. speed of the atoms is equal to the speed of the rock.

Escape velocity of Jupiter would be equivalent to the speed at which an object reaches Jupiter from infinity

Since r.m.s. speed = $(3RT/M)^{1/2}$

$(6 \times 10^4)^2 = 3 \times 8.31 \times T / 0.004$ [1]

$T = 5.78 \times 10^5$ K [1]

temperature = …….. K [2]

(iii) Suggest, with a reason, whether helium-4 gas is found on the surface of Jupiter.

As seen in (ii), for the helium-4 gas molecules to leave Jupiter, it would need to possess a temperature of 5.78×10^5 K. Since the temperature at the surface of Jupiter is way lower than this value (temp of Jupiter is approx. 165 K), it is impossible for helium to possess such a high speed and hence it will be found on the surface of Jupiter.

…… [2]

10 A longitudinal sound wave of wavelength 2.1 m is travelling through a gas causing oscillations of gas molecules that are simple harmonic. The gas molecules are vibrating at a frequency of 835 Hz and have an amplitude of vibration of 610 nm.

(a) Explain what is meant by a *longitudinal* wave.

Longitudinal wave is a wave in which the displacements of the particles in the wave are along the direction of transfer of energy of the wave. [2]

(b) For this sound wave in gas, state the origin of the restoring force on a molecule as it vibrates.

The variation in the pressure of gas resulted in uneven pressure distribution that provides a restoring force on the molecule. [1]

(c) **(i)** Determine, for one vibrating molecule,

1. the maximum speed,

$v = \omega x_0 = (2\pi f)x_0$

$= 2\pi(835)(610\times10^{-9})$ [1]

$= 3.20\times10^{-3}$ m s^{-1} [1]

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

2. the magnitude of maximum acceleration,

$|a_0| = |-\omega^2 x_0|$

$= [(2\pi)(835)]^2(610\times10^{-9})$ [1]

$= 16.8$ m s^{-2} [1]

maximum acceleration = ... m s^{-2} [2]

3. the magnitude of displacement from equilibrium where the vibrational kinetic energy of a gas molecule is half of the maximum vibrational kinetic energy,

$\frac{1}{2}mv^2 = \frac{1}{2}(\frac{1}{2}mv_0^2)$ [1]

$(\omega^2)(x_0^2 - x^2) = 0.5(\omega^2)(x_0^2)$

$x^2 = 0.5x_0^2$

$x = \sqrt{0.5}x_0 = \sqrt{0.5}(610\times10^{-9}) = 431$ nm [1]

displacement = ... m [2]

4. the shortest time interval for kinetic energy to vary from zero to maximum, [1]

$$T = \frac{1}{f}$$

$$T_{displ} = \frac{1}{835} \text{ s}$$

$$T_{energy} = \frac{1}{4}T_{displ} = \frac{1}{4}\left(\frac{1}{835}\right) = 2.99 \times 10^{-4} \text{ s [1]}$$

time 0nterval = ... s [1]

(ii) Determine, for the sound wave,

1. the speed and

$$v = f\lambda = 835(2.1) = 1750 \text{ m s}^{-1} \text{ [1]}$$

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

2. the amplitude.

$$x_0 = 610 \text{ nm [1]}$$

amplitude = ... m [1]

(d) The transmission of sound waves can be affected by several factors such as the medium and the temperature.

(i) State an expression for total energy of a gas molecule due to oscillation caused by the sound wave. The gas molecule has mass *m*, and vibrates with frequency *f* and amplitude x_0.

..... $\frac{1}{2}m(2\pi f)^2 x_0^2$ [1] .....[1]

(ii) Sound waves from a single source were directed to pass through Gas A and Gas B separately. Atoms of Gas A are more massive than that of Gas B. Compare and explain the effect on amplitude of sound waves when they passed through these two gases. [2]

.....

.....

.....

.....

Gas with atoms of larger mass will vibrate with lower amplitude. [1] As energy of wave and hence individual oscillating particle is the same, and frequency of the wave and hence frequency of oscillation does not change, the amplitude will of oscillation and hence wave will be smaller for gas with more massive particle. [1]

(e) A sound wave passes into a 4.0 m pipe that is open at both ends as shown in Fig. 10.1.

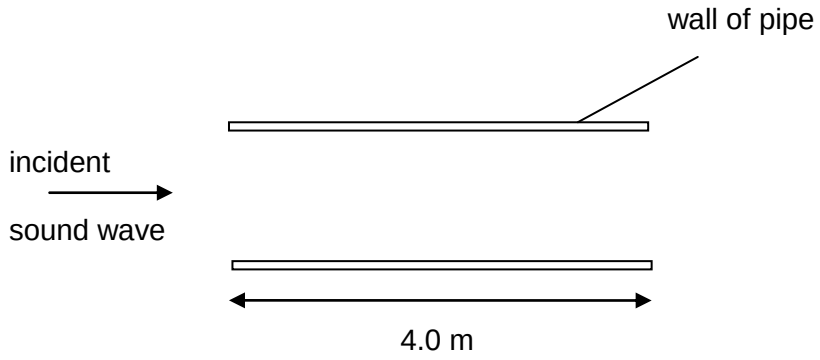


Fig. 10.1

The sound wave travels along the axis of the pipe.

(i) Explain the formation of a stationary (standing) wave in the pipe.

When sound wave reaches open end, it is reflected [1] with incident and reflected waves travelling in opposite direction overlaps. As these waves have same frequency, amplitude and speed, they produce regions of maxima and minima.[1]

[2]

(ii) State 2 possible wavelengths that can form a stationary sound wave within this pipe.

$0.5\lambda = 4.0 \Rightarrow \lambda = 8.0$ m

$\lambda = 4.0$ m [1]

[1]

(iii) Explain why only specific wavelengths will form stationary waves within this pipe.

The open ends of the pipe have to be displacement antinodes hence, creating boundary conditions for forming stationary wave within the pipe. Hence, only specific wavelengths will be able to form stationary waves with antinodes at the open ends. [1]

[1]

(iv) While moving a microphone along the length inside the pipe, loud and soft sounds are detected. State whether loud or soft sound will be detected by the microphone at the open ends of the pipe.

Soft sound. [1]

[1]

END OF PAPER

TEMASEK JUNIOR COLLEGE

2016 Preliminary Examination
Higher 2

PHYSICS

9646/01

Paper 1 Multiple Choice

20 September 2016
1 hour 15 minutes

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 Civics group on the Answer Sheet in the spaces provided.

There are **forty** 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.

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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	v	=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp\left(-2kd\right)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m\left(U - E\right)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp\left(-\lambda t\right)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

1 The behaviour of many real gases deviates from the ideal gas equation $pV_m = RT$. However it can 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 characteristics of the particular gas.

What are the units of a and b?

	a	b
A	Pa m^{-6} mol^2	m^3 mol
B	Pa m^6 mol^{-2}	m^3 mol
C	Pa m^{-6} mol^2	m^3 mol^{-1}
D	Pa m^6 mol^{-2}	m^3 mol^{-1}

2 The acceleration of free fall, g, can be determined using the equation for the period T of a simple pendulum of length L given by

$$T = 2\pi\sqrt{\frac{L}{g}}$$

If the length of the pendulum is measured to be $L = (0.500 \pm 0.001)$ m, and the period is measured to be $T = (1.42 \pm 0.02)$ s, what should the student record as the value of g?

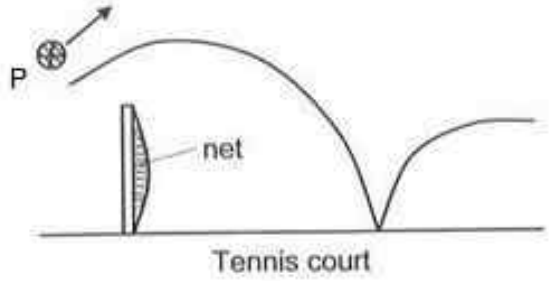
A (9.8 ± 0.3) m s^{-2}

B (9.79 ± 0.03) m s^{-2}

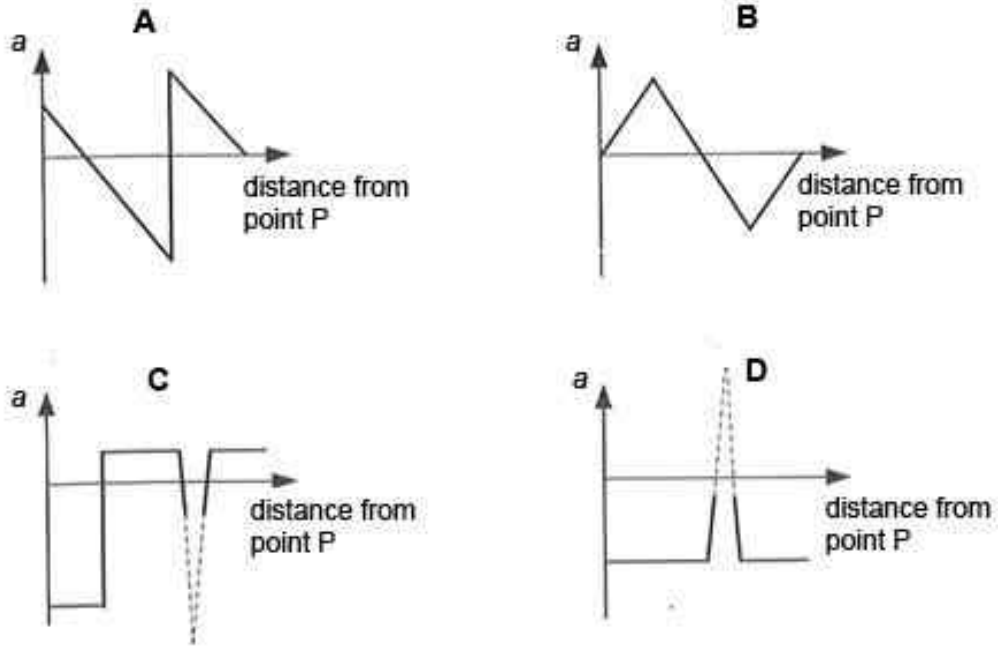
C (9.79 ± 0.30) m s^{-2}

D (9.789 ± 0.295) m s^{-2}

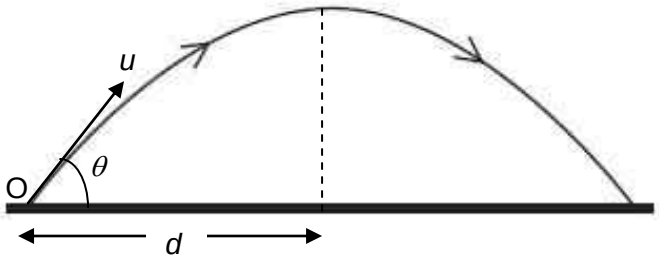
3 The figure below shows the trajectory of a tennis ball crossing the net and bouncing once from the ground.



Which of the following graphs represents the variation with the horizontal distance from point P of the acceleration *a* of the ball, taking the upward direction as positive?



4 Ball X of mass *m* is projected with a speed of *u* at point O at an angle of θ above the ground. It reaches its maximum height when its horizontal displacement is *d*.



Another ball Y of mass 2*m* is projected with a speed of 2*u* from O at the same angle θ above the horizontal.

What is the horizontal displacement of ball Y when it reaches its maximum height? Ignore air resistance.

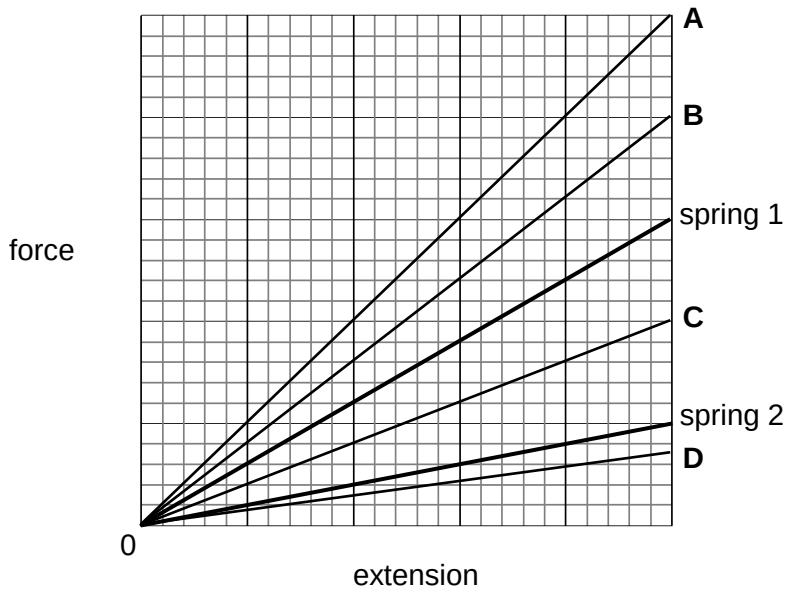
A *d*

B between *d* and 2*d*

C 2*d*

D further than 2*d*

5 Two springs of equal unstretched lengths but different spring constants are subjected to a variable force. The force-extension graphs of both springs are shown in the following diagram.



The springs are then joined in parallel and subjected to the same variable force.

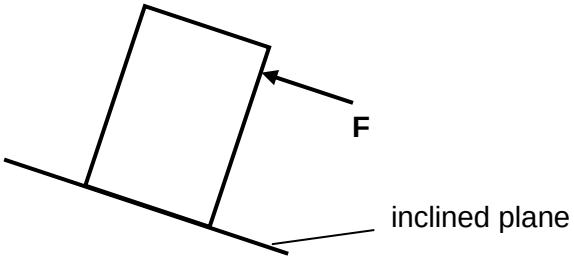
Which of the other lines in the grid would represent the force-extension graph of the two springs joined in parallel?

6 A balloon inflated with helium gas is suspended in air. The total mass of the balloon, helium and load is 80 kg. The density of air is about 0.00123 g cm^{-3}.

Which of the following is the best estimate of the volume of the balloon?

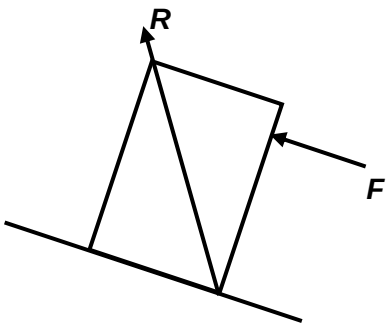
A 65 cm^3 **B** 65 m^3 **C** 638 cm^3 **D** 638 m^3

7 A uniform block rests on a smooth inclined plane, supported by a force *F* to prevent it from moving.

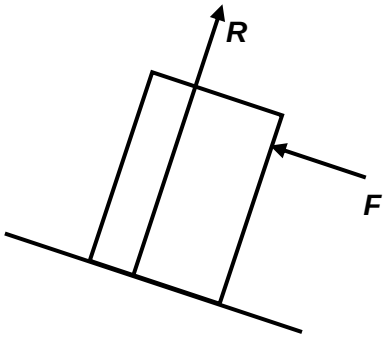


Which of the following diagrams correctly shows the force *R* exerted by the inclined plane on the block?

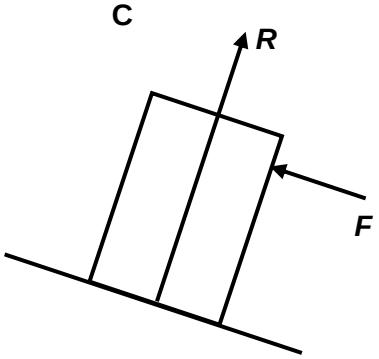
A



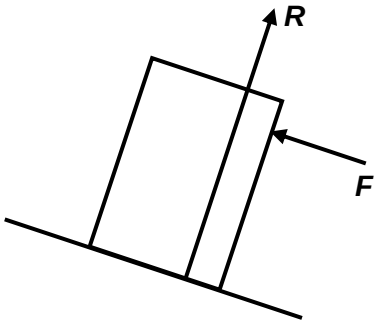
B



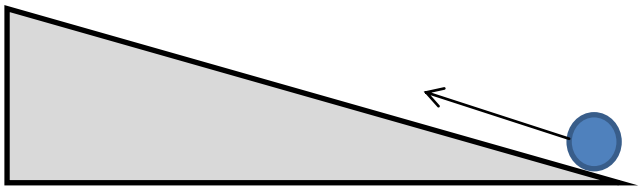
C



D

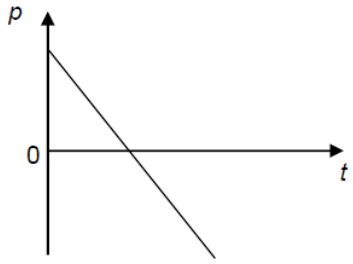


8 An object is projected up a long smooth inclined plane as shown in the diagram.

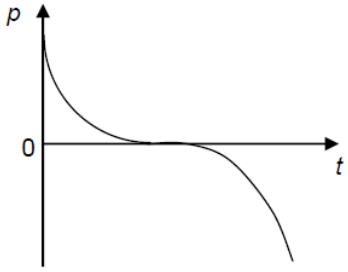


Which graph best shows the variation of the momentum p of the object along the slope with time t?

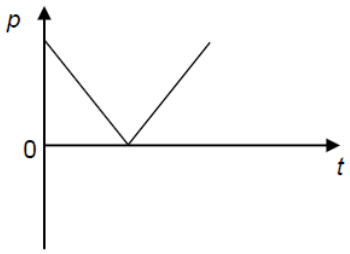
A



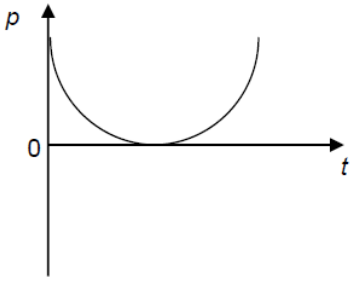
B



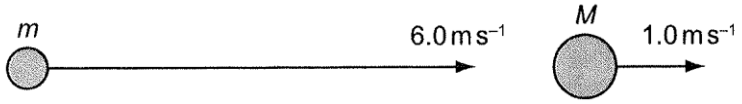
C



D

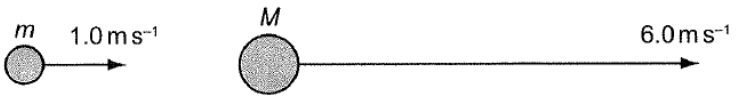


9 A ball of smaller mass m travelling at 6.0 m s^{-1} collides elastically with a ball of larger mass M travelling at 1.0 m s^{-1}.

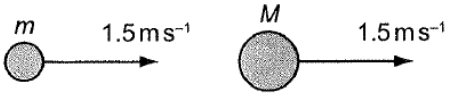


Which diagram represents the velocities of the two balls after the collision?

A



B



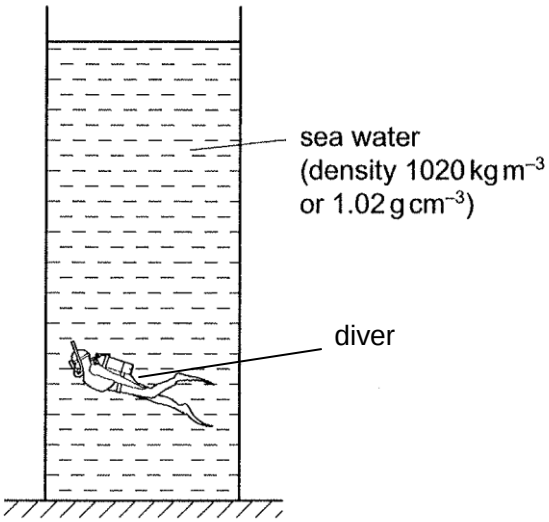
C



D



10 The diagram shows a tall water-filled tower used for training divers.



Which of the following gives the rate of change of pressure with depth in this tower?

A 1.0 Pa m^{-1}

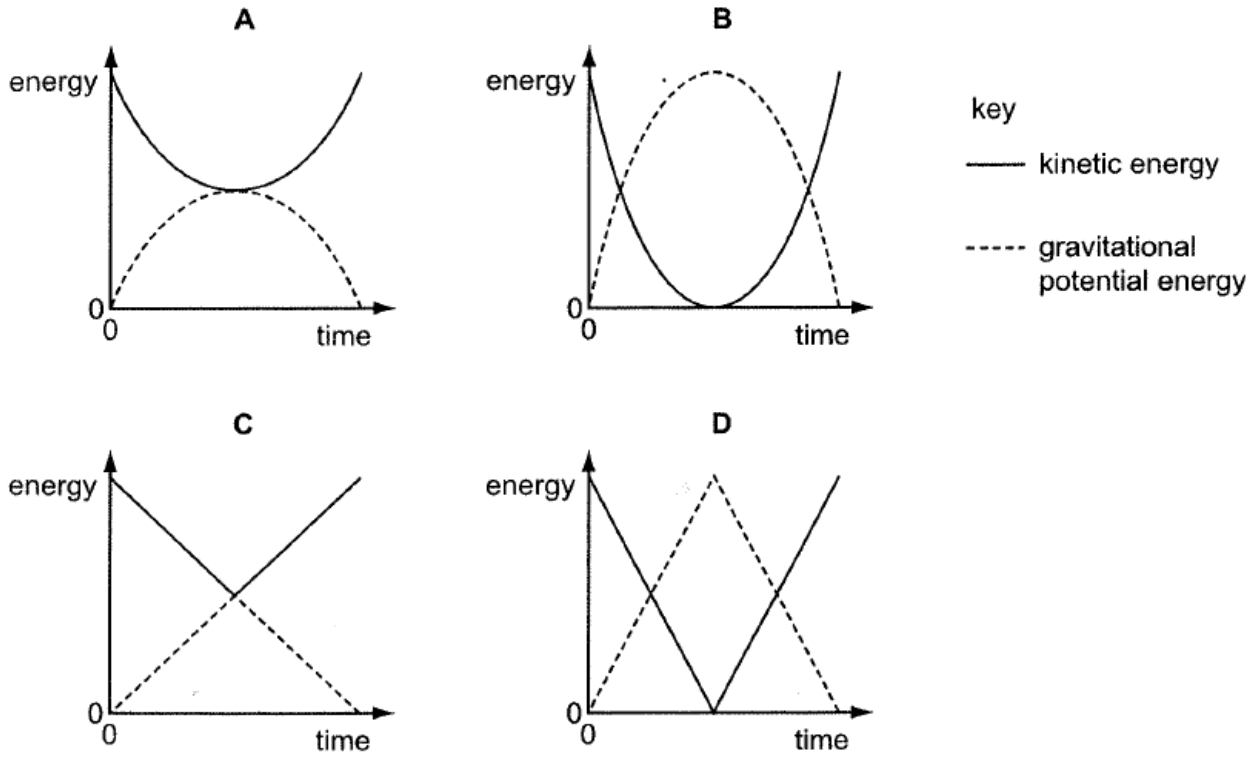
B 10 Pa m^{-1}

C 1.0 x 10^{3} Pa m^{-1}

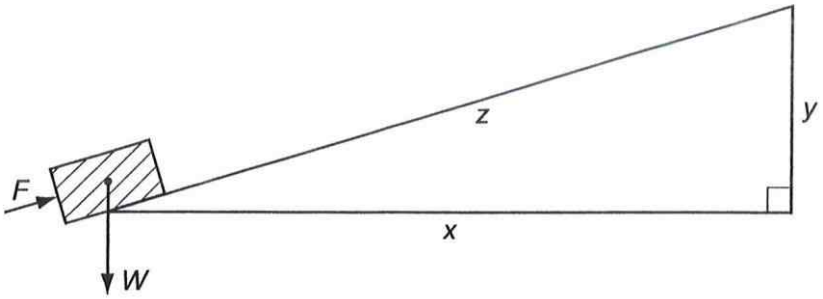
D 1.0 x 10^{4} Pa m^{-1}

11 A soccer player hits a ball so that it leaves the ground at an angle of 45° to the horizontal.

Which graph represents the variation of kinetic energy and of gravitational potential energy with time of the ball during the time of flight? Assume that air resistance can be ignored.



12 A block of weight *W* rests on a rough slope of dimensions, *x*, *y* and *z* as shown.

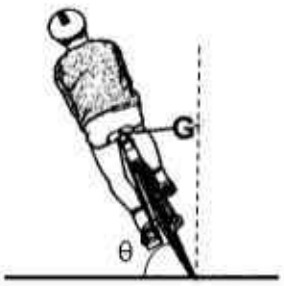


A force *F* pushes the block all the way up the slope. The block starts and finishes at rest.

How much work is done by the force *F*?

A *Wy* **B** *Wy* + *Fz* **C** *Wz* **D** *Fz*

13 A boy on a cycle pedals around a circle of radius 30 m at a speed of 20 m s^{-1}. G is the centre of gravity of the boy and cycle. The combined mass of the boy and the cycle is 90 kg.



What is the angle θ that he makes with the horizontal so that he may not fall?

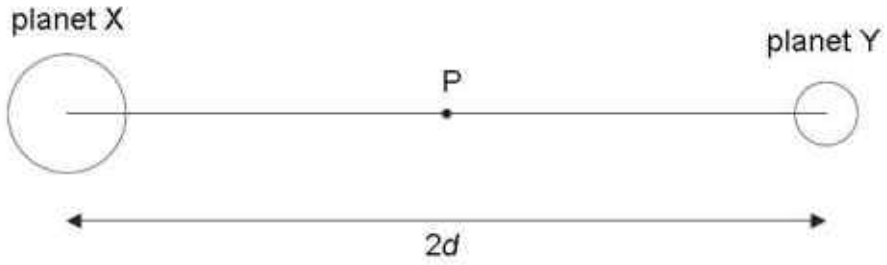
A 13° **B** 36° **C** 54° **D** 86°

14 A satellite is moved from a low orbit to a higher orbit.

Which of the following accurately describes the energy of the satellite?

	total energy	gravitational potential energy	kinetic energy
A	stays the same	decreases	increases
B	stays the same	increases	decreases
C	increases	decreases	increases
D	increases	increases	decreases

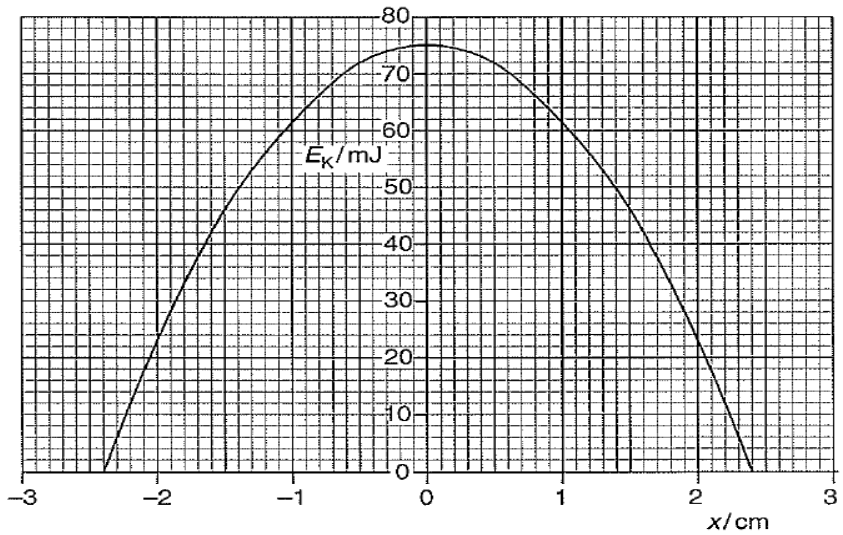
15 The diagram below shows two planets X and Y of masses 2*M* and *M* respectively. The centres of the two planets are separated by a distance 2*d*. Point P is midway between planets X and Y. The mass of each planet may be assumed to be concentrated at its centre.



What are the gravitational field strength and the gravitational potential at point P due to the two planets?

	gravitational field strength at P	gravitational potential at P
A	$\frac{GM}{d^2}$	$-\frac{3GM}{d}$
B	$\frac{GM}{d^2}$	$-\frac{GM}{d}$
C	$\frac{3GM}{d^2}$	$-\frac{GM}{d}$
D	$\frac{3GM}{d^2}$	$-\frac{3GM}{d}$

16 A particle undergoes simple harmonic motion. The variation of the kinetic energy E_K of the particle with displacement x from its equilibrium position is shown in the figure below.



The particle loses energy so that its maximum kinetic energy is reduced by 50 mJ.

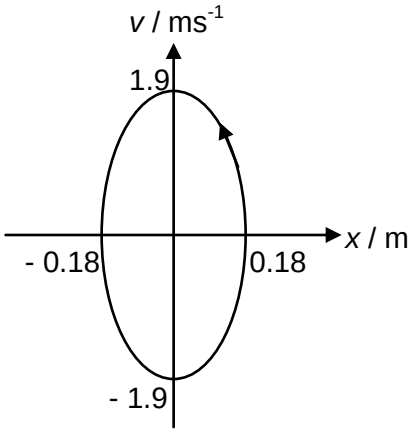
What is the amplitude of the oscillations?

A 2.4 cm **B** 1.9 cm **C** 1.4 cm **D** 0.95 cm

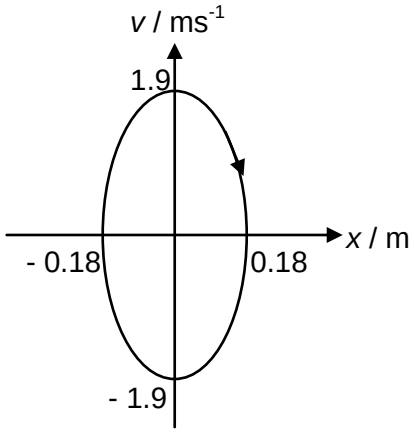
17 An object is undergoing simple harmonic motion between two extreme points. It takes 0.30 s to travel from one extreme point to the other. The distance between these two points is 0.36 m.

Which of the following shows the correct velocity-displacement graph describing the motion? The arrow on each graph gives the direction in which the graph would be mapped out as time progresses.

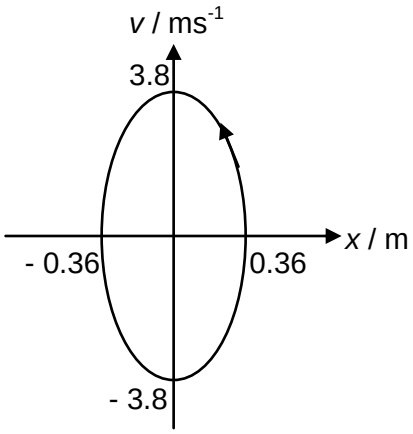
A



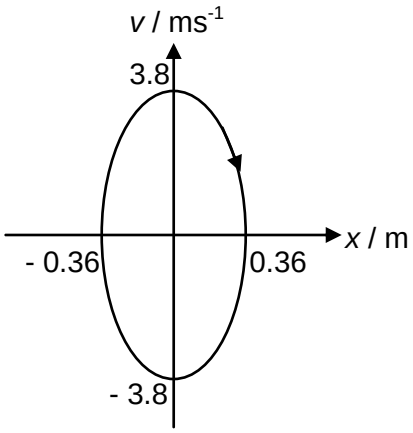
B



C



D



18 Equal masses of water and alcohol, initially at different temperatures, T_w and T_a respectively, are mixed together.

If $T_w < T_a$ and the specific heat capacity of water is greater than that of alcohol, which of the following regarding the final temperature T of the mixture is true?

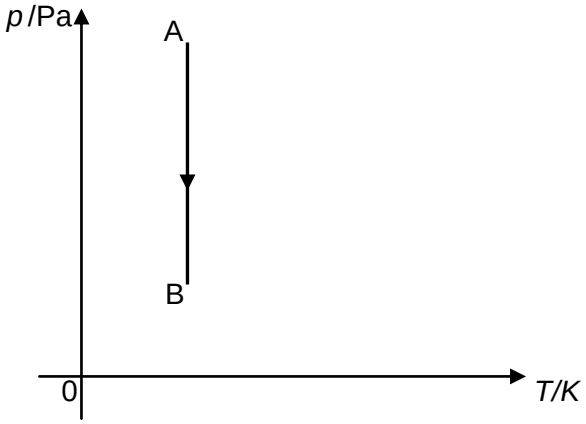
A $T = T_w + T_a$ **B** $T = ½ (T_w + T_a)$ **C** $T < ½ (T_w + T_a)$ **D** $T > ½ (T_w + T_a)$

19 An ice cube and an iceberg are both at a temperature of 0 ^{o}C.

Which of the following is a correct comparison of the average kinetic energy and the total kinetic energy of the molecules of the ice cube and the iceberg?

	average kinetic energy	total kinetic energy
A	same	same
B	same	different
C	different	same
D	different	different

20 A fixed mass of an ideal gas undergoes a process from A to B as shown in the *p* - *T* diagram.

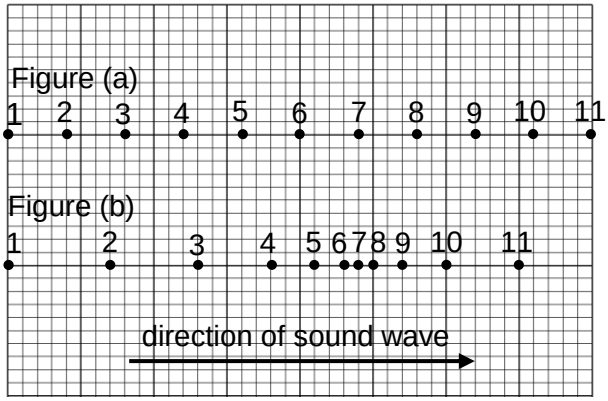


Which of the following deductions about the heat transfer and work done on the gas is correct?

	heat transfer	work done on the gas
A	out of the gas	zero
B	into the gas	zero
C	out of the gas	non-zero
D	into the gas	non-zero

21 Figure (a) shows the positions of equally spaced molecules in a solid lattice.

A longitudinal sound wave travels from left to right through the solid. At a certain instant, the displaced positions of the molecules are shown in Figure (b).

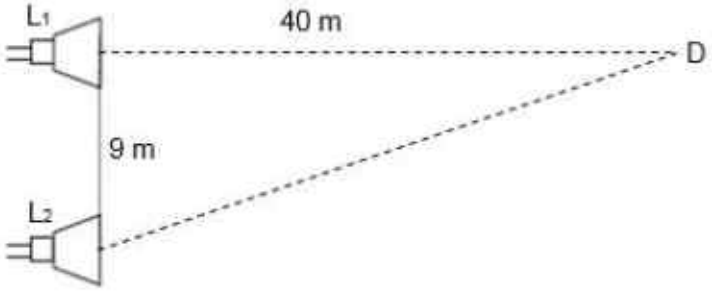


Immediately afterwards, what will be the directions of motion of particles 1 and 7?

	particle 1	particle 7
A	to the right	to the right
B	to the right	to the left
C	to the left	to the right
D	to the left	to the left

22 Two loudspeakers L_1 and L_2, placed 9 m apart, are driven by a common oscillator as shown in the diagram.

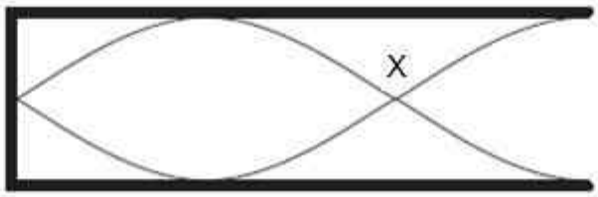
As the frequency of the oscillator increases from zero, the detector at D, placed 40 m from L_1, recorded a series of maximum and minimum signals.



If the speed of sound is 330 m s^{-1}, at what frequency is the first maximum detected?

A 165 Hz **B** 330 Hz **C** 495 Hz **D** 660 Hz

23 A standing wave is established in air in a pipe with one closed and one open end.



Which of the following correctly describes the air molecules near X?

A always at the centre of a compression.

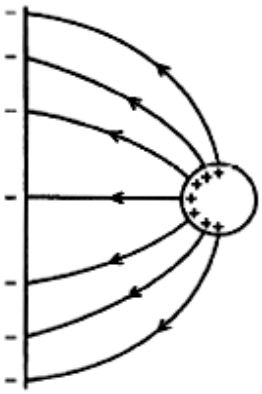
B always at the centre of a rarefaction.

C alternately at the centre of a compression and at the centre of a rarefaction.

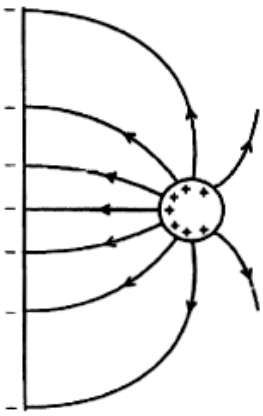
D never at the centre of a compression or a rarefaction.

24 Which is the correct electric field pattern between a charged conducting sphere and a metal plate placed near it?

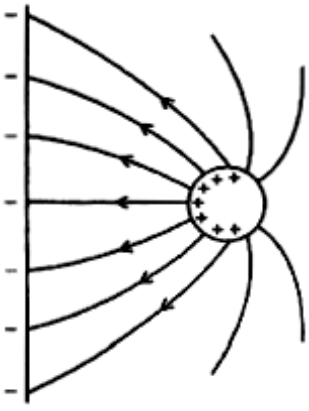
A



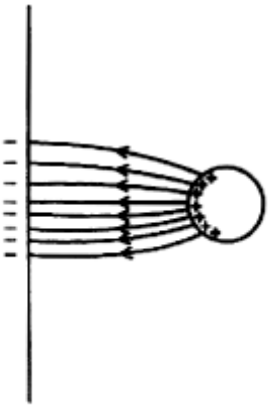
B



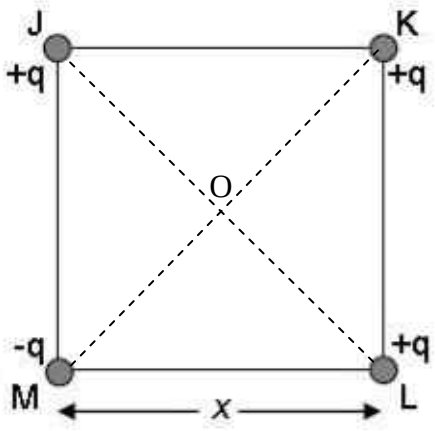
C



D



25 Four point charges, each of magnitude q, lie at the four corners J, K, L, M of a square. The signs of the charges are shown in the diagram. The side of the square is of length x.



What is the electric field strength at the centre O of the square?

A $\frac{q}{\pi\varepsilon_O x^2}$ towards K

B $\frac{q}{\pi\varepsilon_O x^2}$ towards M

C $\frac{q}{2\pi\varepsilon_O x^2}$ towards K

D $\frac{q}{2\pi\varepsilon_O x^2}$ towards M

26 A filament lamp is described as being “120 V, 60 W”. The lamp is connected to a supply so that it lights normally.

Which statement is correct?

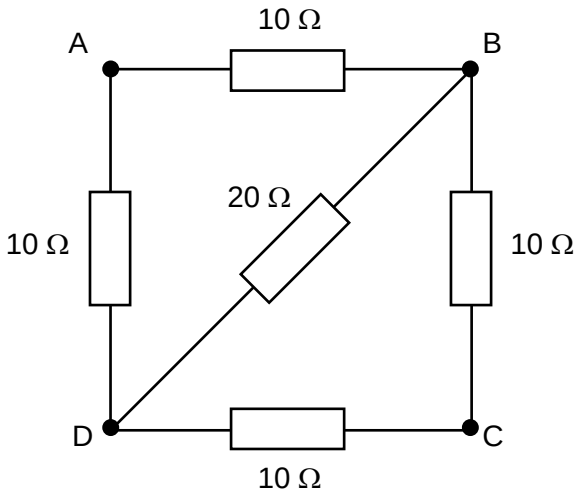
A The charge passing through the filament in one second is 2.0 C.

B The lamp transfers 60 J for 1.0 C of charge passing through the filament.

C The lamp transfers 120 J in 2.0 s.

D The supply provides 60 J to the lamp when the current is 2.0 A.

27 In the circuit shown, four identical resistors of resistance 10 Ω are connected in a square with a 20 Ω resistor connected across the diagonal. A fixed p.d. is connected across BD.



How will the power to the circuit change if the same p.d. is connected across AB instead?

A The power will remain the same.

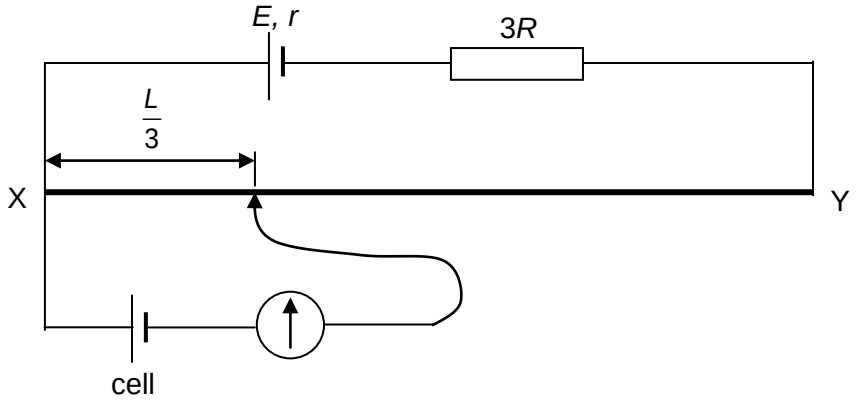
B The power will decrease.

C The power will increase.

D Not enough information to determine how the power will change.

28 A potentiometer has a wire XY of length *L* and resistance *R*. It is powered by a battery of e.m.f. *E* and internal resistance *r* in series with a resistor of resistance 3*R*.

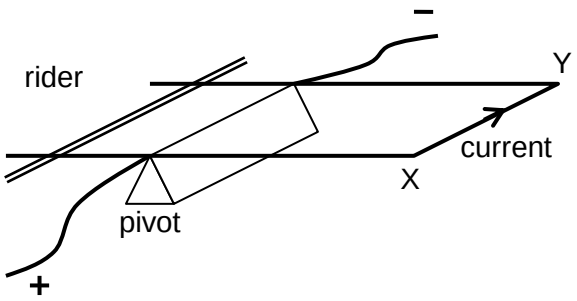
With another cell in the branch circuit, the null point is found to be $\frac{L}{3}$ from X, as shown below.



What is the e.m.f. of the cell?

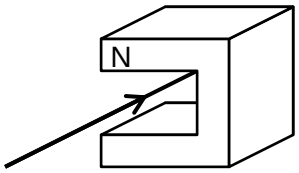
A $\frac{E}{12}$ **B** $\frac{ER}{3(3R+r)}$ **C** $\frac{ER}{4R+r}$ **D** $\frac{ER}{3(4R+r)}$

29 The diagram below shows a current balance used to determine the strength of a magnet.

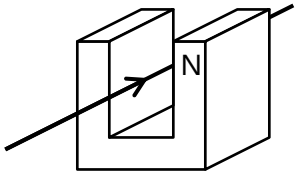


Which of the following shows the correct placement of the magnet relative to XY?

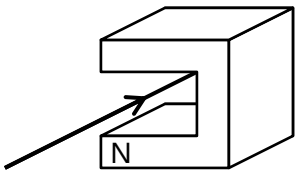
A



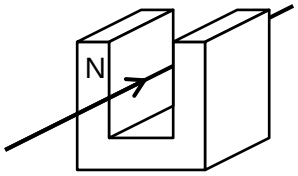
B



C



D

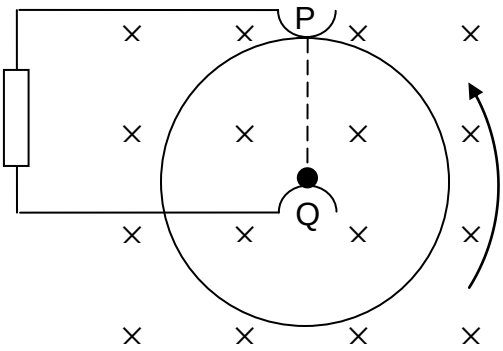


30 A doubly charged ion is moving in a uniform magnetic field of flux density B in a circle of radius r at a speed v.

What is the flux density of the field which will maintain a singly charged ion of the same mass in a circle of half the radius at the same speed?

A $\frac{B}{4}$ **B** $\frac{B}{2}$ **C** $2B$ **D** $4B$

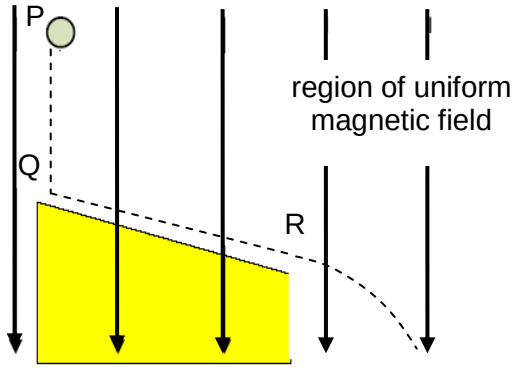
31 The diagram shows a metal disc rotating anti-clockwise in a uniform magnetic field.



Which of the following describes the direction of current along radius PQ and the potential of P with respect to Q?

	direction of current along radius PQ	potential of P with respect to Q
A	P to Q	lower
B	Q to P	lower
C	Q to P	higher
D	P to Q	higher

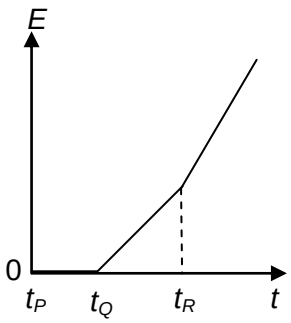
32 The diagram shows the cross-section of a metal rod at position P within a region of uniform magnetic field. The rod falls vertically from rest and lands on a smooth slope at position Q. It continues to roll down and off the slope at position R.



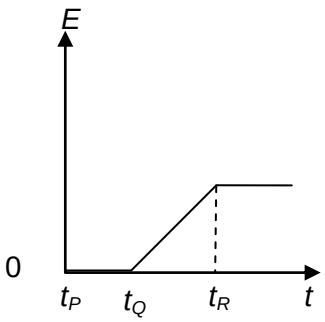
At times t_P, t_Q and t_R, the rod is at the positions P, Q and R respectively.

Which of the following graphs shows the variation of the induced e.m.f. E in the rod with time t from the time it is released? Neglect any resistive force.

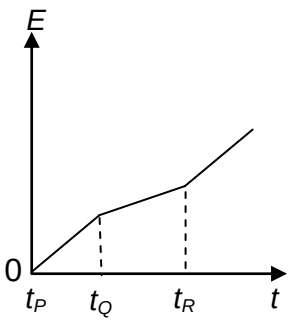
A



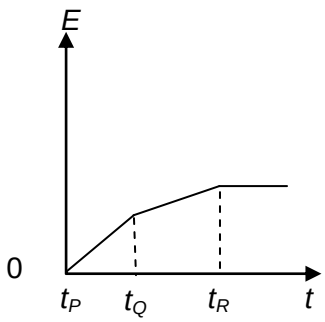
B



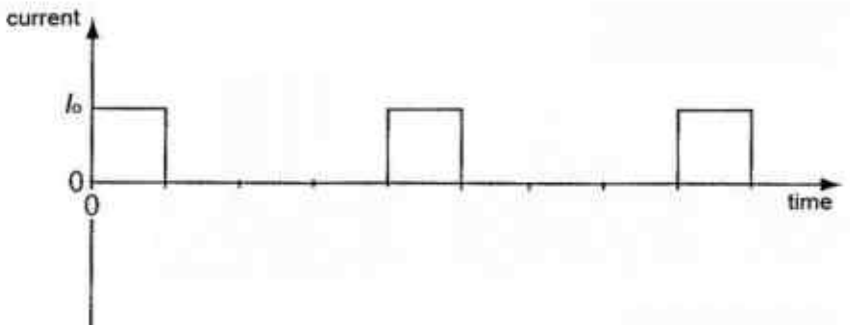
C



D



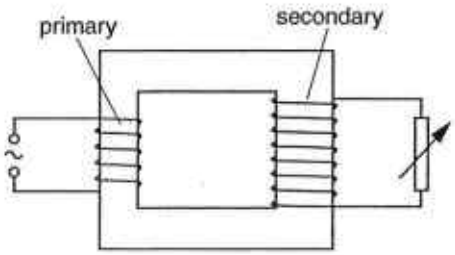
33 The graph shows the rectified waveform of an alternating current. The peak value of the current is I_o.



What is the root-mean-square value of the current?

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

34 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 cross-sectional area of the secondary coil

B increasing the current in the primary coil

C increasing the number of turns of the primary coil

D increasing the resistance of the variable resistor

35 Light of frequency f incident on a given metal surface produces photoelectrons with a maximum kinetic energy K.

If light of frequency $2f$ is used, what is the maximum kinetic energy of the photoelectrons?

A 0 **B** less than $2K$ **C** $2K$ **D** more than $2K$

36 Transitions between three energy levels in a particular atom give rise to the three spectral line of frequencies, in increasing magnitudes f_1, f_2 and f_3.

Which one of the following equations correctly relates f_1, f_2 and f_3?

A $\frac{1}{f_1} = \frac{1}{f_2} + \frac{1}{f_3}$ **B** $f_1 = f_2 + f_3$ **C** $f_3 = f_1 + f_2$ **D** $f_3 = f_2 - f_1$

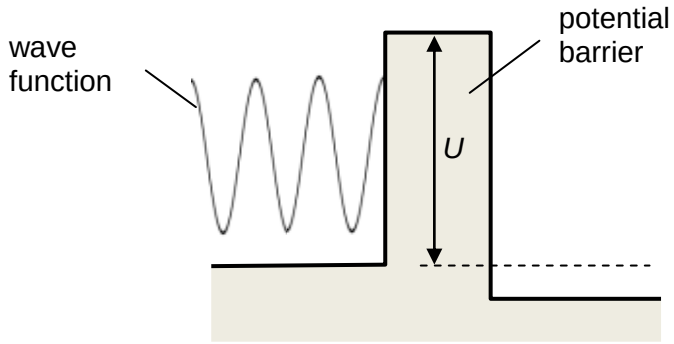
37 An electron of mass m travelling with speed u collides with an atom and its speed is reduced to v. The speed of the atom is unaltered, but one of its electrons is excited to a higher energy level and then returns to its original state, emitting a photon.

If h is the Planck constant, what is the frequency of the photon?

A $\frac{m(u^2 - v^2)}{2h}$ **B** $\frac{m(v^2 - u^2)}{h}$ **C** $\frac{m(u^2 + v^2)}{2h}$ **D** $\frac{mv^2}{2h}$

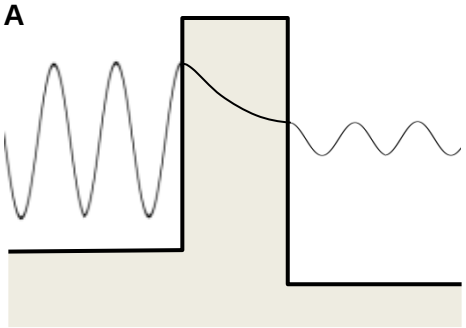
38 An electron of energy E is incident on the left-hand side of a potential barrier as shown.

The potential barrier has a height of U. The energy U is greater than E.

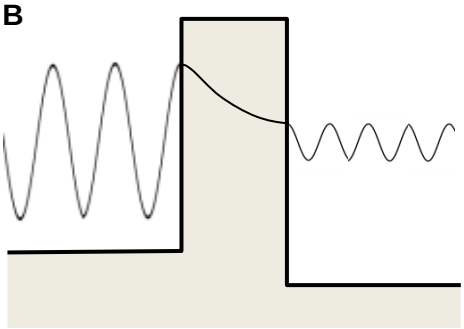


Which diagram represents the wave function of the electron to the right of the barrier?

A



B



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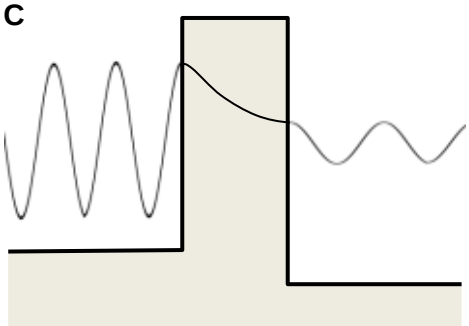

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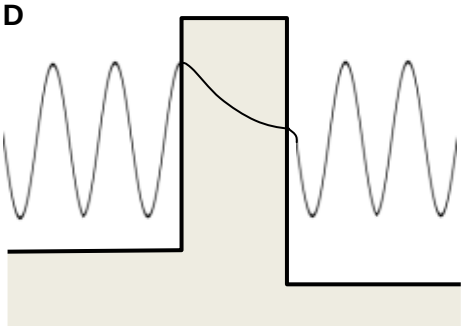


39 The isotope $^{226}_{88}Ra$ decays into $^{222}_{86}Rn$ with the emission of an α-particle and a gamma-ray photon of frequency f.

Which of the following expressions demonstrates the principle of conservation of mass-energy?

A $226 = 222 + 4$

B $\left[m_{Ra} - m_{Rn}\right]c^2 = hf$

C $\frac{1}{2}m_{Rn}u_{Rn}{}^2 = hf + \frac{1}{2}m_{\alpha}u_{\alpha}{}^2$

D $\left[m_{Ra} - \left(m_{Rn} + m_{\alpha}\right)\right]c^2 = hf + \frac{1}{2}m_{\alpha}u_{\alpha}{}^2 + \frac{1}{2}m_{Rn}u_{Rn}{}^2$

40 A sample contains 2 radioactive nuclides X and Y. The half-lives of X and Y are 1 day and 2 days respectively. Initially, the number of nuclei of X is the same as that of Y.

If the initial activity of the sample is A_0, what is its activity 4 days later?

A $\frac{A_0}{6}$ **B** $\frac{A_0}{8}$ **C** $\frac{A_0}{9}$ **D** $\frac{A_0}{12}$

TEMASEK JUNIOR COLLEGE

2016 Preliminary Examination
Higher 2

CANDIDATE NAME

CIVICS GROUP

INDEX NUMBER

PHYSICS

9646/02

Paper 2 Structured Questions

31 August 2016
1 hour 45 minutes

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

READ THESE INSTRUCTION FIRST

Write your Civics group, index 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.

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	
8	

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	=	ρgh
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	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	=	$R_1 + R_2 + \ \ldots$
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	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{1/2}}$

1 A bomber, shown in Fig. 1.1, is flying horizontally at a speed of 72 m s^{-1} and at a height of 100 m above the ground. When directly flying over the origin O, bomb B is released and it strikes a truck T, which is moving along a level road with a constant speed *v*. At the instant the bomb is released, the truck T is at a distance x_o = 125 m from origin O.

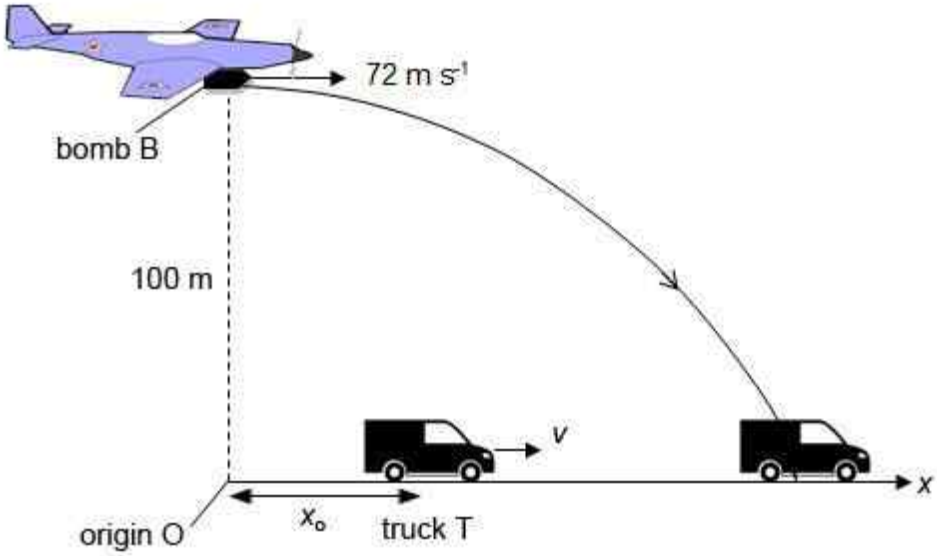


Fig. 1.1

(a) Write an expression, in terms of the quantities given,

(i) the horizontal displacement *x* of bomb B at time *t* after it is dropped,

.....

[1]

(ii) the vertical displacement *y* of bomb B at time *t* after it is dropped.

.....

[1]

(b) Calculate the time of flight of bomb B upon striking the truck T.

time of flight = ... s [2]

(c) **(i)** On the same axes in Fig. 1.2, sketch graphs showing the variation with time *t* of the horizontal displacement *x* for the bomb B and truck T. Label the graphs B and T respectively, indicating appropriate values on the graphs.



Fig. 1.2

[2]

(ii) From the graphs sketched in (c)(i) or otherwise, determine the speed *v* of truck T.

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

2 **(a)** State the conditions for an object to be equilibrium.

.....

.....

..... [2]

(b) A uniform ladder of length 12.0 m and mass 40 kg rest on a wall. The lower end of the ladder is at 6.0 m from the wall as shown in Fig. 2.1. The wall is smooth while the ground is rough.

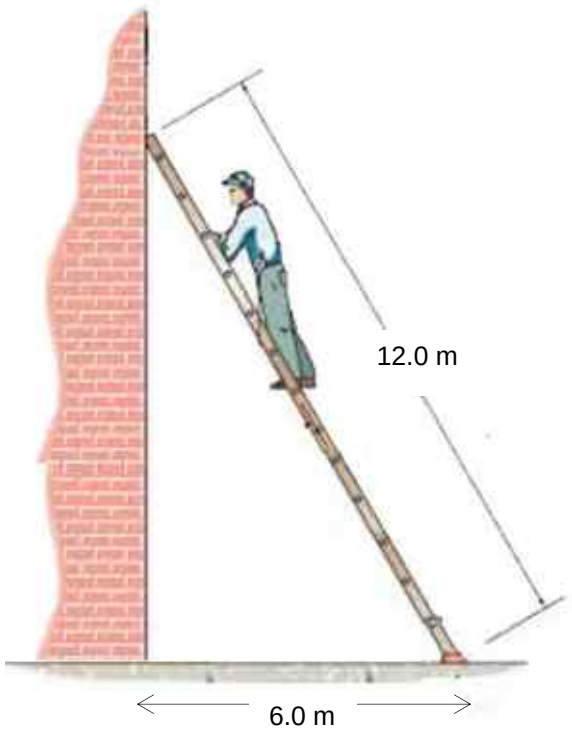


Fig. 2.1

A man of mass 72 kg starts to climb up the ladder. When the man is ¾ way up the ladder, he feels that the ladder is beginning to slip.

(i) On Fig 2.1, sketch the free-body diagram of the ladder, indicating all forces clearly.

[2]

(ii) Calculate the normal contact force by the ground on the ladder.

normal contact force = ... N [2]

(iii) Calculate the normal contact force by the wall on the ladder.

normal contact force = ... N [2]

3 **(a)** Define *electrical resistance* of a conductor.

.....

..... [1]

(b) Fig. 3.1 shows a circuit containing five identical lamps A, B, C, D and E. The circuit also contains three switches S_1, S_2 and S_3.

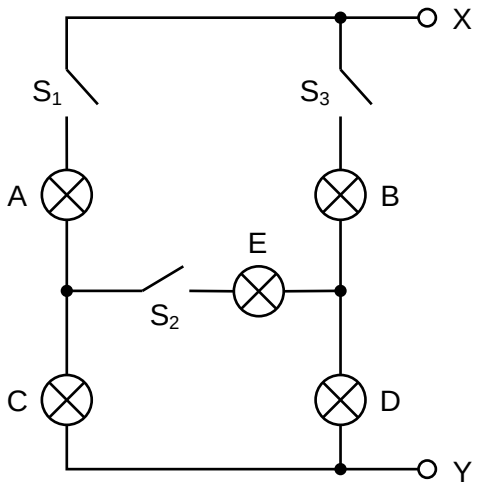


Fig. 3.1

One of the lamps is faulty. In order to detect the fault, an ohm-meter (a meter that measures resistance) is connected between terminals X and Y. When measuring resistance, the ohm-meter causes negligible current in the circuit.

Fig. 3.2 shows the readings of the ohm-meter for different switch positions. The resistance of the non-faulty lamps is assumed to be constant.

.....

switch			metre reading
S_1	S_2	S_3	/ Ω
open	open	open	∞
closed	open	open	30.0
closed	closed	open	22.5
closed	closed	closed	15.0

Fig. 3.2

(i) Explain how it can be deduced from the results in the table that the resistance of each lamp is 15 Ω.

.....

.....

..... [1]

(ii) Identify the faulty lamp and the nature of the fault.

faulty lamp: .....

nature of fault: .....

..... [2]

(iii) Suggest why it is advisable to test the circuit using an ohm-meter that causes negligible current rather than with a power supply across terminals X and Y.

.....

.....

[1]

(iv) Each lamp is marked 12.0 V, 0.50 A.

Calculate, for one of the lamps operating at normal brightness,

1. its resistance,

resistance = ... Ω [1]

2. its power dissipation.

power dissipation = ... W [1]

(v) Explain why the resistance calculated in **(iv)1** is different from the value obtained in **(i)**.

.....

.....

..... [1]

4 *Mass Spectrometry* is a powerful technique for identifying unknown substances, studying molecular structures, and probing the fundamental principles of chemistry. Some applications of mass spectrometry include identifying and quantifying pesticides in water samples, detecting steroids in athletes, determining metals at parts per quadrillion levels in water and carbon-dating. One of the essential components of the spectrometer is the velocity selector.

(a) Illustrate, in the spaces provided, how you would arrange a pair of electric and magnetic fields to enable velocity selection of a **positive** ion.

[2]

(b) The parallel plates providing the electric field are placed 15.0 cm apart and a potential difference of 3000 V is applied across the plates.

Determine the required flux density of the magnetic field such that carbon ions, each carrying a charge of +1.60 x10^{-19} C and moving at a speed of 3.70 $\times$ 10^{6} m s^{-1} inside the fields, experience no deflection.

magnetic flux density = ... T [2]

(c) After the carbon ions passed through the velocity selector, they subsequently enter a region of uniform magnetic field as shown in Fig. 4.1.

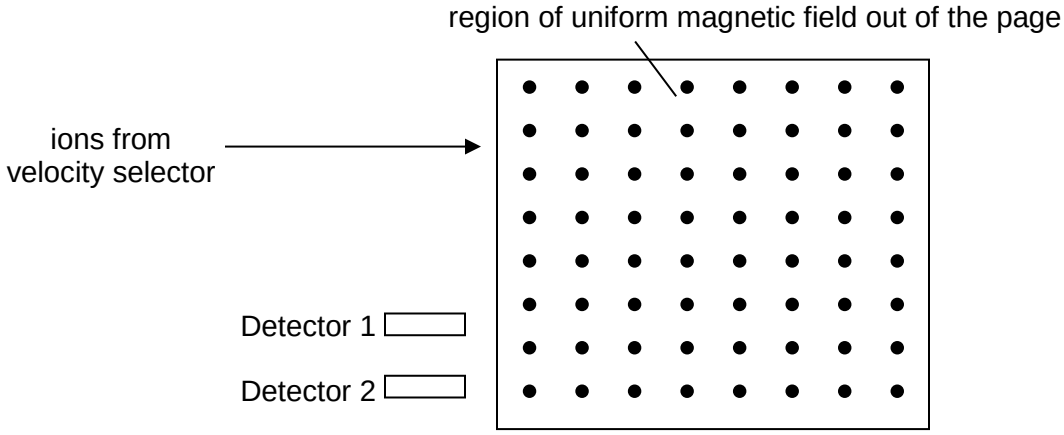


Fig. 4.1

Detectors 1 and 2 each detects either carbon-12 ions or carbon-14 ions only.

(i) Explain with the help of relevant equation(s), how ions of carbon-12 and carbon-14 are differentiated in this region of magnetic field.

.....

.....

.....

.....

.....

..... [3]

(ii) On Fig. 4.1, sketch the path of the carbon-12 ions in the magnetic field before it enters into its corresponding detector. [1]

5 *Pumping* is the excitation of electrons from the ground state to an excited state, and is a necessary process in the operation of a laser in order to achieve *population inversion*.

(a) Explain what is meant by *population inversion*.

.....

..... [1]

(b) Explain why the pumping process is necessary to achieve population inversion.

.....

..... [1]

(c) One of the ways to pump is to use a strong flash lamp to excite the atoms in the laser. This is called *optical pumping*.

Explain why it is not practical to achieve population inversion using optical pumping if the laser operates between just two energy levels (i.e. a 2-level laser), as illustrated in the schematic diagram Fig. 5.1.

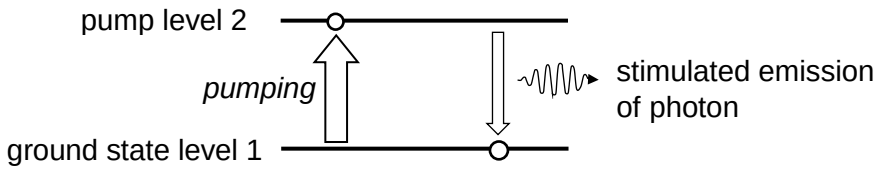


Fig. 5.1

.....

.....

..... [1]

(d) In a 3-level laser shown in Fig. 5.2, atoms excited by the pumping process to pump level 3 quickly decays to an intermediate level 2, which becomes the upper lasing level.

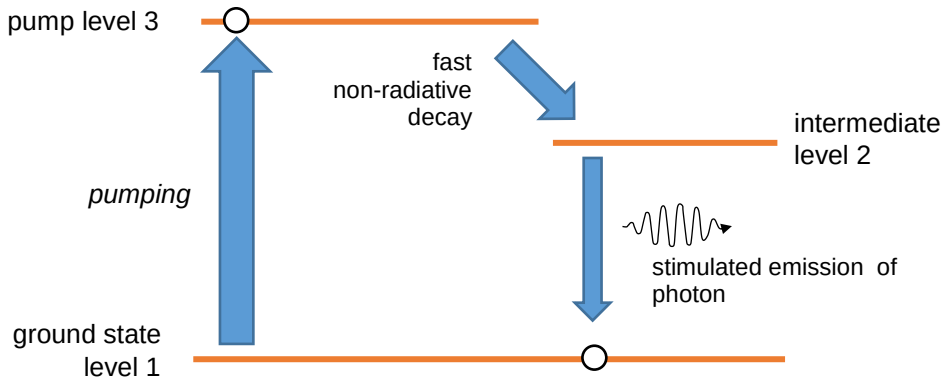


Fig. 5.2

State and explain a necessary property of this intermediate level 2 for lasing to occur.

.....

.....

.....

..... [2]

6 Fig. 6.1 shows the variation of binding energy per nucleon for nuclides with a nucleon number greater than 40.

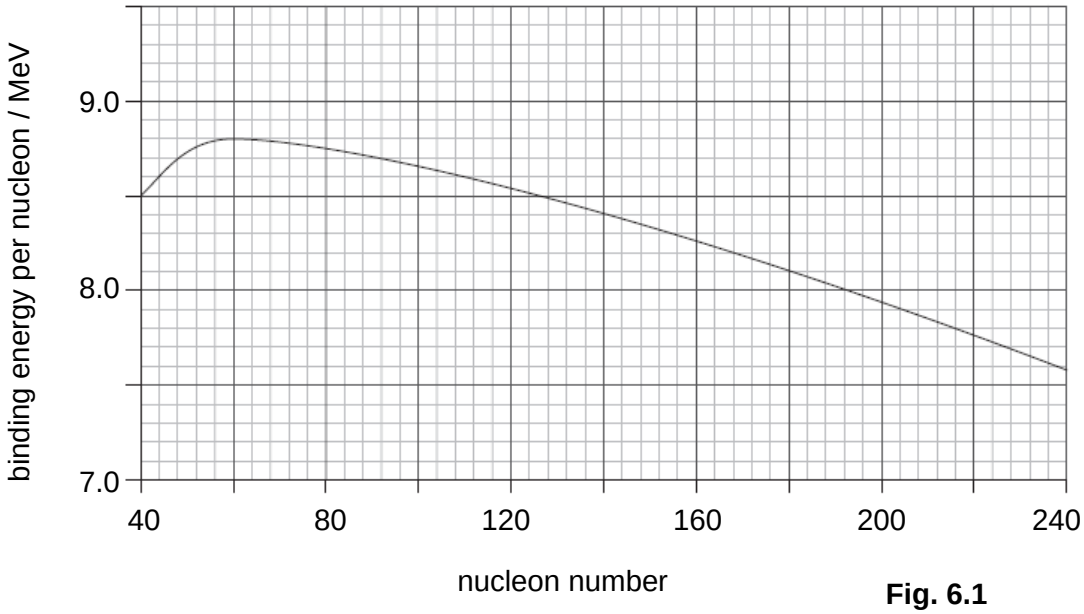


Fig. 6.1

(a) Explain what is meant by *binding energy*.

.....

.....

..... [1]

(b) A nucleus of Uranium-235 (U-235) fissions into Barium-141 (Ba-141) and Krypton-92 (Kr-92). The equation for this fission is

$$^{235}_{92}\mathrm{U} = {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + x\,{}^{1}_{0}\mathrm{n}\,.$$

(i) State the value of x in the equation.

x = ... [1]

(ii) Use Fig. 6.1 to show that the fission of one nucleus of U-235 will release about 190 MeV of energy.

[4]

(iii) Hence or otherwise, calculate the number of U-235 nuclei that must undergo fission in order to release 1.0 kJ of energy.

number of U-235 nuclei = ... [1]

(iv) State the form in which the energy released in each fission reaction would appear as.

..... [1]

7 A photoresistor or light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity; in other words, it exhibits photoconductivity.

An LDR is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance. The electrons released from bonds in the material of the LDR by absorbing incident photons remain free to conduct for about 50 ms before returning to be localised in bonds again.

Fig. 7.1 shows a plot of the resistance *R* of the LDR against the intensity I of incident light on a logarithmic scale.

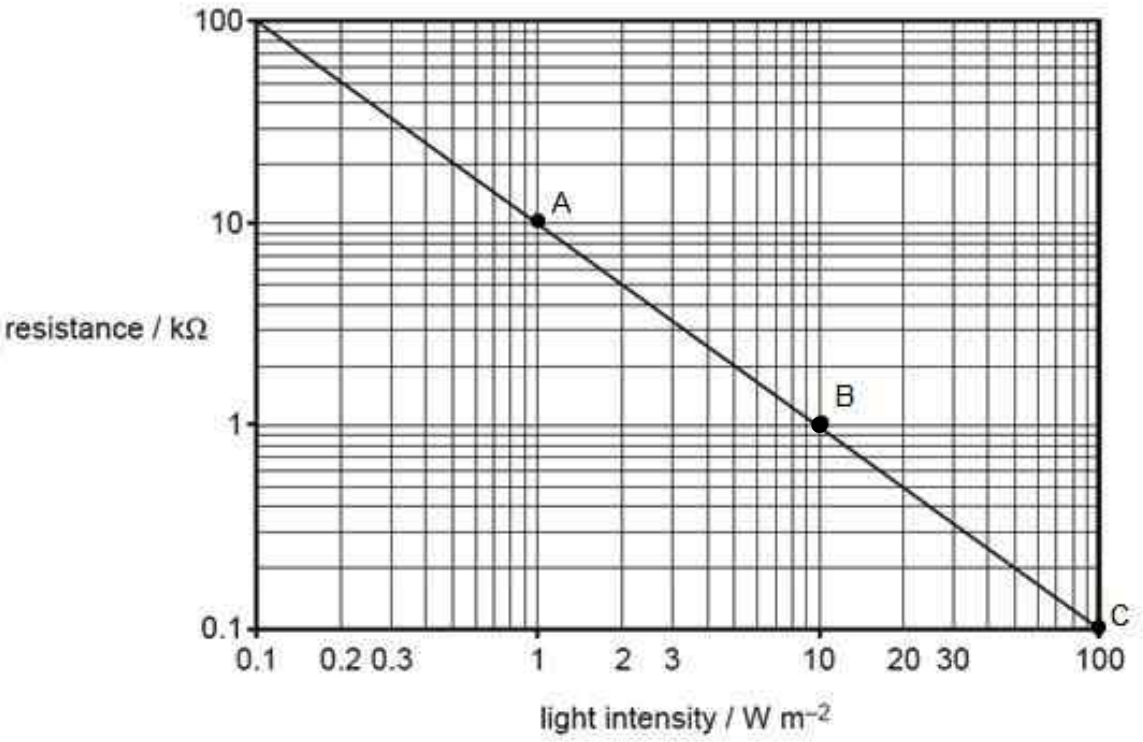


Fig. 7.1

(a) **(i)** Use Fig. 7.1 to find the resistance of the LDR at a light intensity of 50.0 W m^{-2}.

resistance of LDR = ... Ω [1]

(ii) Explain the advantage of plotting the resistance-intensity graph on the logarithmic scale.

.....

.....

..... [1]

(iii) It is thought that the resistance *R* of the LDR is related to the intensity I of incident light by a relation of the form

$$R = 10000I^{-1}.$$

Explain how the relation may be verified using Fig. 7.1.

.....

.....

.....

.....

..... [2]

(b) Together with the data point in (a)(i), transfer the data points A, B, C in Fig. 7.1 to the grids in Fig. 7.2 to plot the graph of resistance *R* vs intensity I on a normal scale.

Draw a best-fit curve through the points. [2]

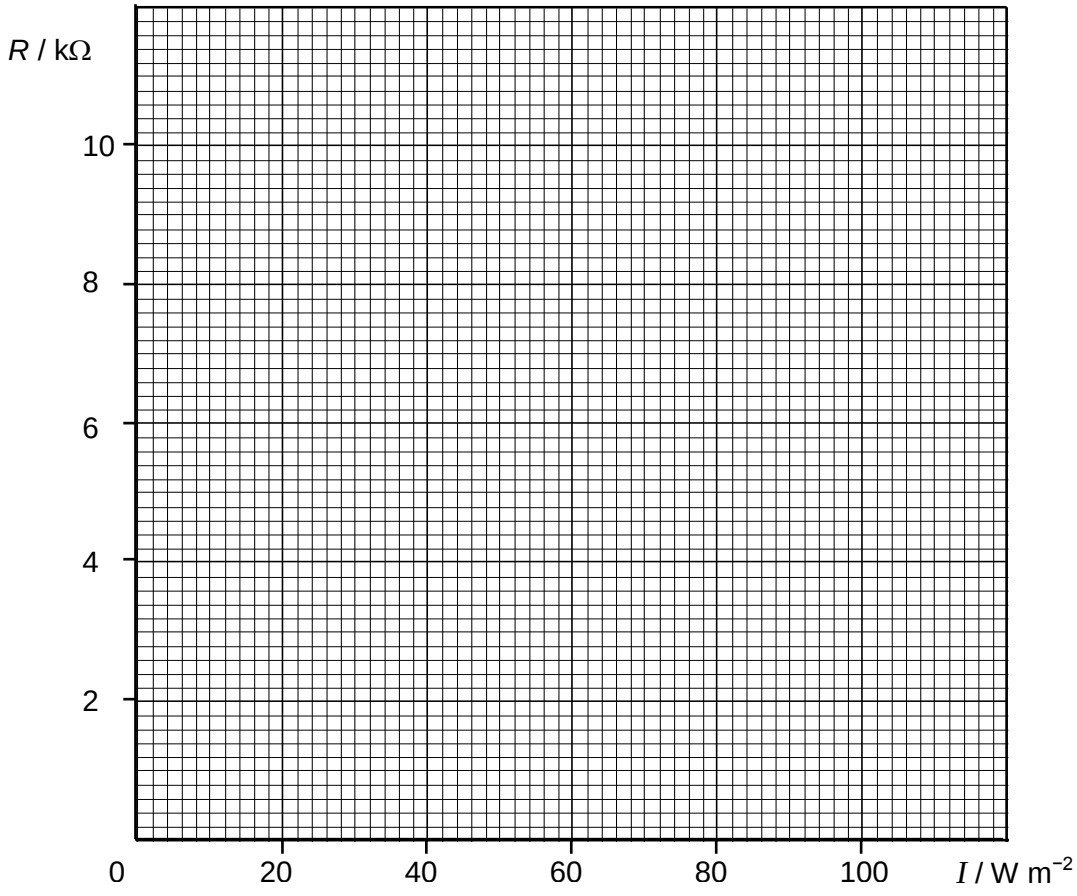


Fig. 7.2

(c) The LDR is connected in series with a variable resistor *X* and a 12.0 V d.c. supply. The buzzer is connected across the variable resistor *X* as shown in Fig. 7.3. The buzzer is set to sound if the potential difference across it is equal to or greater than 9.0 V.

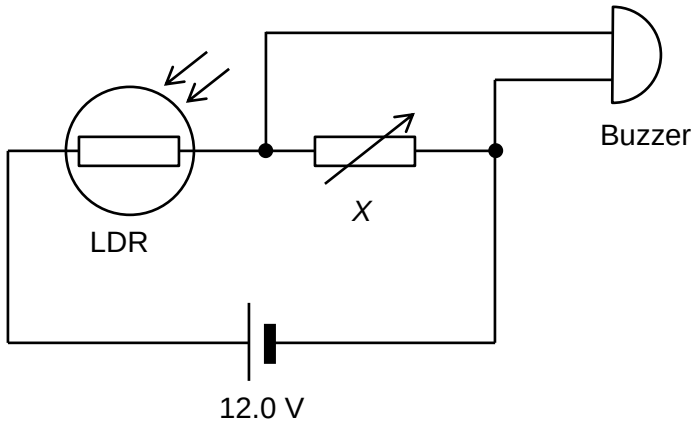


Fig. 7.3

(i) Calculate the value of the resistance of *X* if we want the buzzer to sound when the light intensity exceeds 50.0 W m^{-2}.

resistance of *X* = ... Ω [3]

(ii) Suggest an application for the circuit in Fig.7.3 and explain how it works.

.....

.....

.....

..... [2]

(iii) Explain why it is impractical to use this LDR as a trigger for light intensity below 1.0 W m^{-2}.

.....

.....

.....

..... [2]

(iv) State how you would modify the circuit if you want the buzzer to sound

1. for falling light intensity.

.....

.....

..... [1]

2. for increasing temperature.

.....

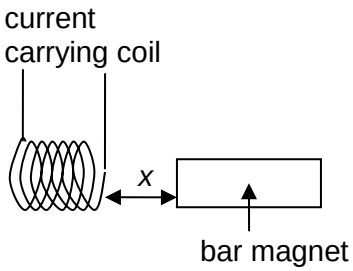
.....

..... [1]

8 Magnets are used in many products, such as televisions, telephones, computers, audio systems and automobiles.

There is a concern that the magnets will affect the operational efficiency of one another in the same area. For instance, many electrical systems use conducting coils. When a current flows in a coil, it produces a magnetic field which can exert a force on other systems in the surrounding.

Design an experiment to investigate how the attractive force that a current carrying coil acts on a bar magnet varies with the distance *x* between their closest ends as shown below.



You may use any standard equipment usually found in a Physics laboratory.

You should draw a labelled diagram to show the arrangement of the 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 force and distance is determined from your readings,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

[12]

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TEMASEK JUNIOR COLLEGE

2016 Preliminary Examination
Higher 2

CANDIDATE NAME			
CIVICS GROUP		INDEX NUMBER	

PHYSICS

9646/03

Paper 3 Longer Structured Questions

16 September 2016
2 hours

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

READ THESE INSTRUCTION FIRST

Write your Civics group, index 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.

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

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	
2	
3	
4	
5	
6	
7	
8	
Total	

This booklet consists of **22** printed pages.

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	=	ρgh
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
	v	=	$\pm\omega\sqrt{\left(x_0^2 - x^2\right)}$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{0.693}{t_{1/2}}$

Section A

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

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.

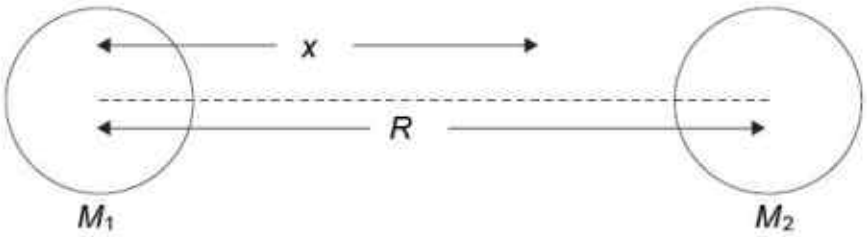


Fig. 1.1

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.

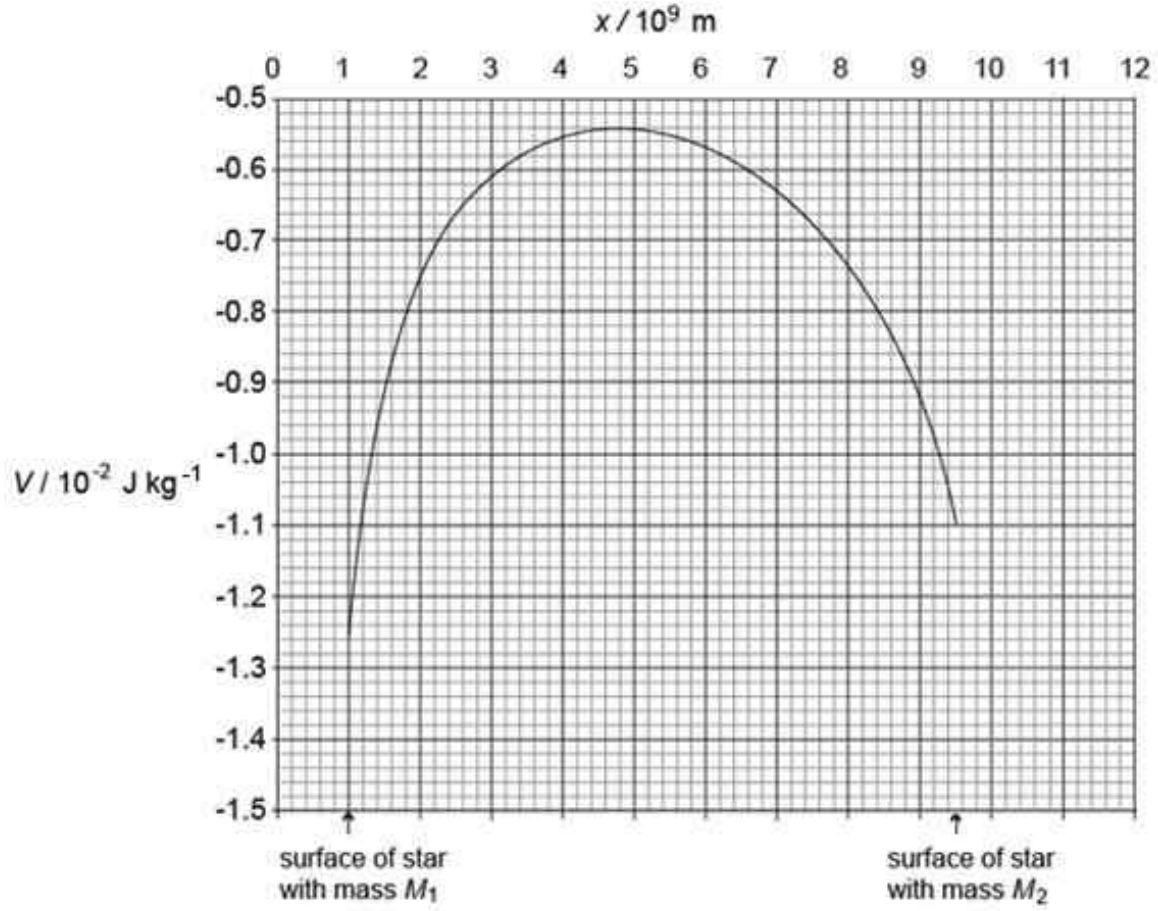


Fig. 1.2

A particle is launched with kinetic energy E_K from the surface of star with mass M_2.

The particle arrives at the surface of the star of mass M_1.

(a) Explain what is meant by the term *gravitational potential*.

.....

.....

..... [1]

(b) Use the graph to explain whether the kinetic energy of the particle when it arrives at the surface of M_1 is less than, equal to, or larger than its initial kinetic energy E_K.

.....

.....

.....

..... [2]

(c) Determine the distance x at which the gravitational field strength due to the two stars is zero. Explain how you arrive at the answer.

x = ... m

.....

.....

..... [2]

(d) Determine the ratio $\frac{M_1}{M_2}$.

ratio = ... [2]

2 The graph in Fig. 2.1 shows the variation of the pressure p with volume V of a fixed mass of an ideal gas.

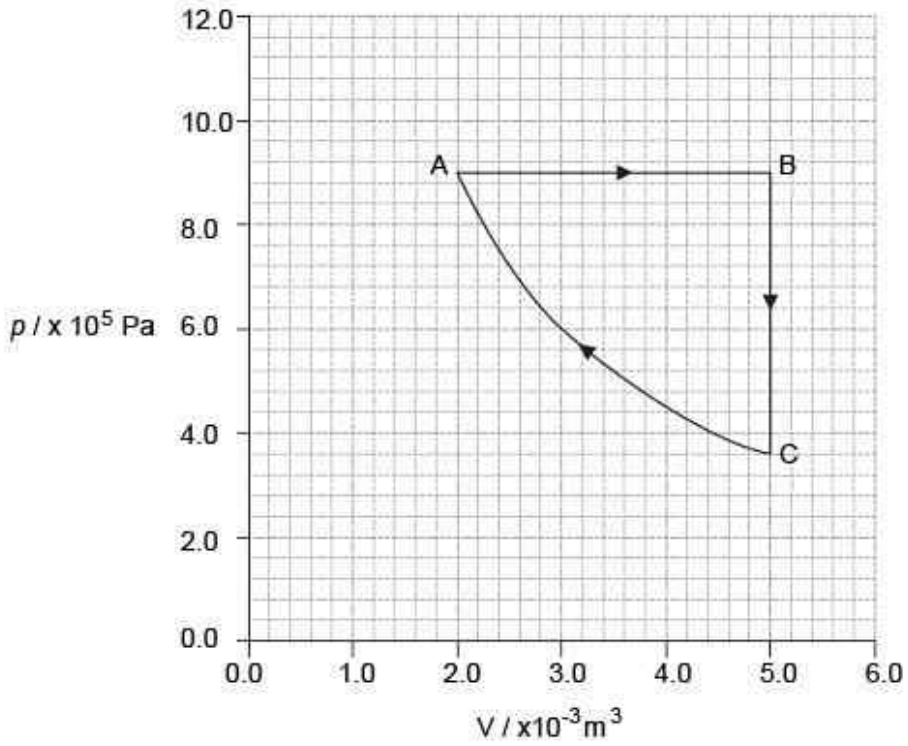


Fig. 2.1

The gas undergoes a three-stage cycle, AB, BC and CA.

(a) State the *First Law of Thermodynamics*.

.....

.....

.....

..... [1]

(b) The amount of gas used is 0.74 mol. Calculate the maximum temperature of the gas during the cycle ABCA.

maximum temperature = ... K [2]

(c) Show that the work done by the gas in the process AB is 2700 J.

[1]

(d) State the value of the change in internal energy for the cycle ABCA. Explain how you arrive at the answer.

.....

..... [1]

(e) Hence or otherwise, explain whether heat is given out or absorbed during the cycle ABCA.

.....

.....

.....

..... [2]

3 A 0.20 kg mass oscillates vertically on a spring as shown in Fig 3.1.

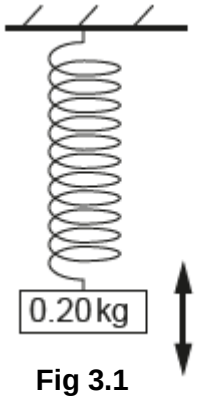


Fig 3.1

Fig 3.2 shows the variation of acceleration with the displacement of the mass on the spring.

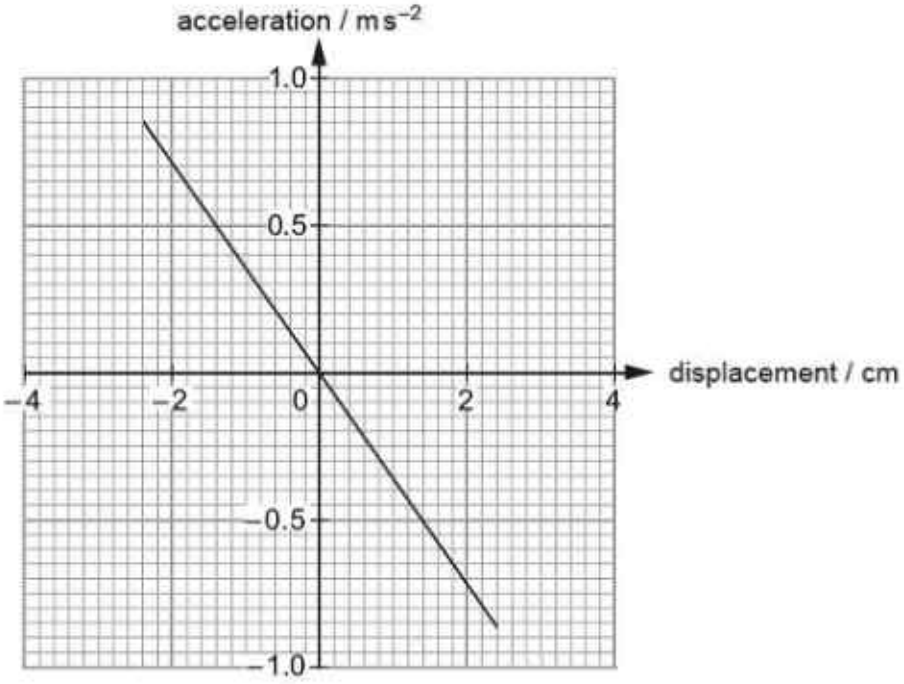


Fig 3.2

(a) Use the graph to

1. show that the period of oscillation of the mass is 1.05 s.

[2]

2. calculate the maximum kinetic energy of the mass.

maximum kinetic energy = ... mJ [2]

(b) If the mass is moving upwards at its maximum speed at t = 0 s, determine the time taken for the mass to move through a distance of 1.5 cm .

time = ... s [2]

(c) Sketch a graph on Fig. 3.3 to show the variation with time of the kinetic energy of the mass for two cycles, indicating appropriate values on your graph.



[2]

Fig. 3.3

4 **(a)** Define *electric potential* at a point.

.....

..... [1]

(b) Fig. 4.1 shows a small charged particle at a point A in a uniform electric field. The particle experiences an electric force *F* of 5.00 x 10^{-7} N. The grid lines in the figure are at intervals of 1.0 cm.

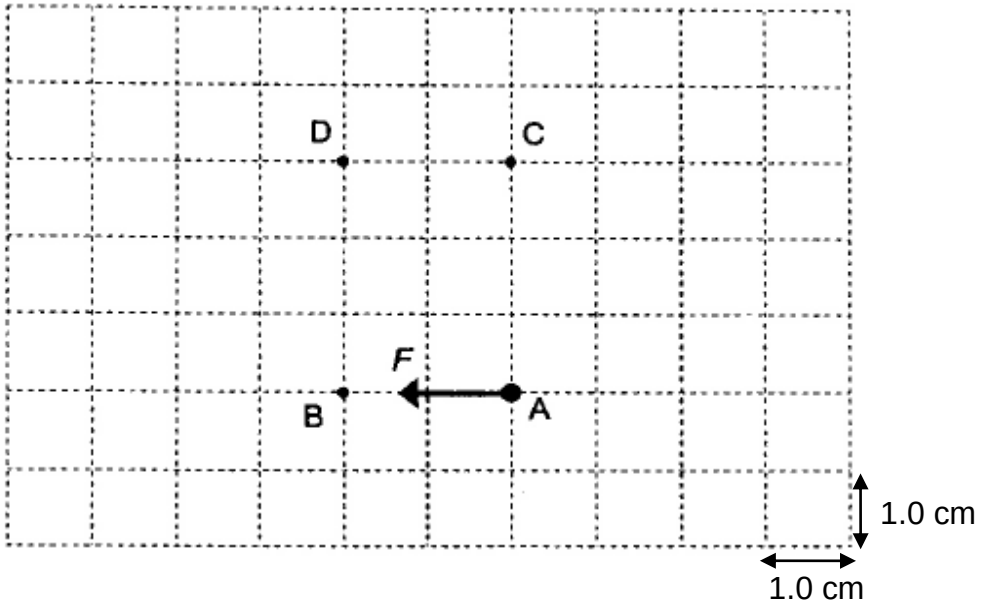


Fig. 4.1

Calculate the work done by the electric force if the particle is moved

(i) from A to B,

W_{AB} = ... J [1]

(ii) from A to C,

W_{Ac} = ... J [1]

(iii) from A to D.

W_{AD} = ... J [1]

(c) If the particle carries a charge of - 2.50 x 10^{-11} C and point A is at a potential of +200 V, calculate the potential at point B due to the uniform field.

potential at B = ... V [2]

(d) If the uniform electric field is produced by a pair of flat metal plates, one of which is earthed and the other is at a potential of +1000 V, sketch on Fig. 4.1 the positions of the two plates.

[2]

(e) Hence sketch, on Fig. 4.1, at least four equipotential lines in the region between the two plates. Label the value of the potential of each line that is drawn. [2]

5 Two parallel rails of negligible resistance are placed 15.0 cm apart as shown in Fig. 5.1. Two metal rods, AB and CD, which can slide smoothly along the rails, are being pulled away by external forces. Rod AB is being pulled at a constant speed of 3.0 m s^{-1} while rod CD is being pulled at a constant speed of 5.0 m s^{-1} in the opposite direction. There is a uniform magnetic field strength of 0.20 T applied perpendicular to the plane of the rails into the paper.

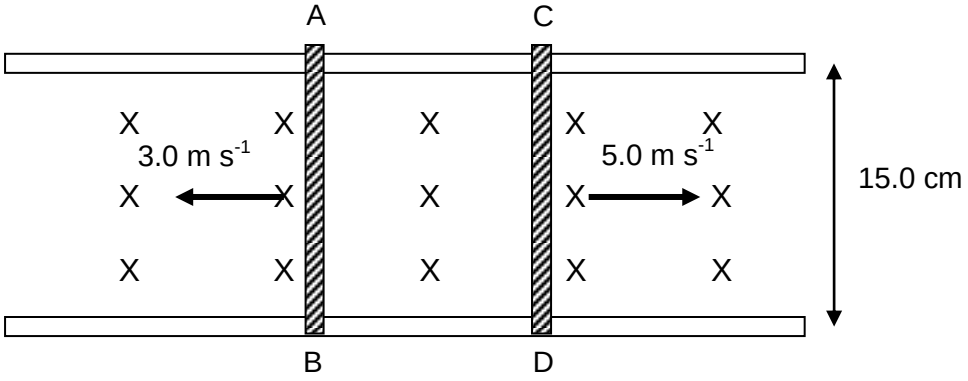


Fig. 5.1

(a) Using Faraday's law of electromagnetic induction, explain why an e.m.f. is induced in the loop ABDCA.

.....

.....

.....

..... [2]

(b) Calculate the magnitude of the e.m.f. induced in the loop ABDCA.

e.m.f. induced = ... V [2]

(c) State and explain the direction of the induced current in the loop ABDCA.

.....

.....

.....

..... [2]

(d) Rod AB is now being pulled at 3.0 m s^{-1} in the same direction as rod CD as shown in Fig. 5.2.

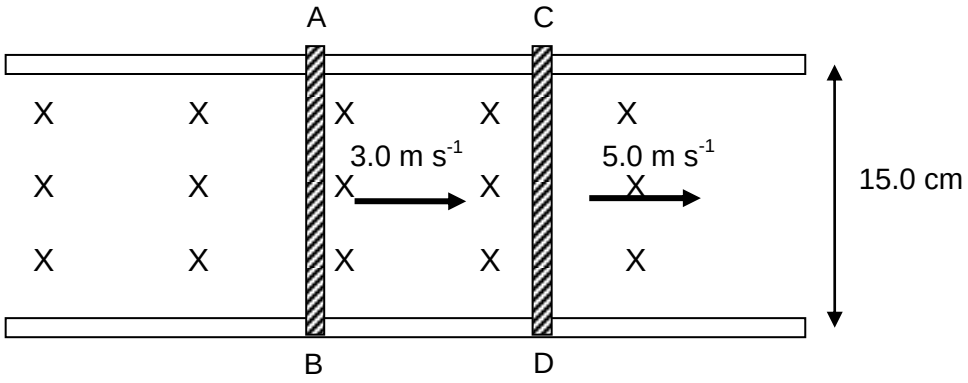


Fig. 5.2

Explain whether the e.m.f. induced in the loop ABDCA will have a smaller or larger magnitude compared to that calculated in 5(b).

.....

.....

.....

..... [2]

Section B

Answer **two** questions from this section.

6 **(a)** Explain what is meant by a *force*.

.....

.....

[1]

(b) Fig. 6.1 shows a jet aircraft preparing for take-off along a horizontal runway.



Fig. 6.1

The maximum force produced by the engine is 28 kN. The take-off speed of the jet is 56 m s^{-1}. The mass of the jet is 6200 kg.

(i) Calculate the minimum distance the jet travels from rest to the point where it takes off.

distance = ... m [3]

(ii) Explain why the runway needs to be longer than the distance calculated in (i).

.....

.....

.....

.....

[2]

(iii) State and explain why after the jet has taken off and is flying horizontally for some time, it will reach its maximum velocity.

.....

.....

.....

[2]

(c) The jet is to be used in a flying display in which the pilot will be required to fly the jet in a horizontal circle of radius r, at a constant speed of 86 m s^{-1}. This is achieved by flying the jet with its wings at an angle θ to the horizontal, as shown in Fig. 6.2.

With the jet in this way, the two forces acting on the jet are the lift L and the weight W.

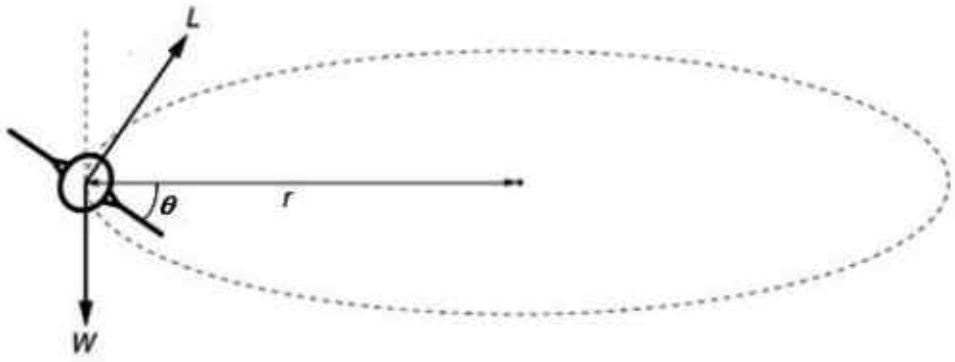


Fig. 6.2

(i) Explain why, at the position shown in Fig. 6.2, the jet is able to move in a horizontal circular motion.

.....

.....

.....

..... [2]

(ii) If the angle θ is 35°, show that the magnitude of the lift L is about 74 kN.

[1]

(iii) Calculate the radius r.

r = ... m [2]

(iv) If the pilot wishes to fly at the same speed but at a larger radius of horizontal circle, should the angle θ be more or less than 35°? Explain why.

.....

.....

[2]

(d) In a more complex manoeuvre, the pilot is required to fly in a vertical circle of radius 240 m at a constant speed as shown in Fig. 6.3.

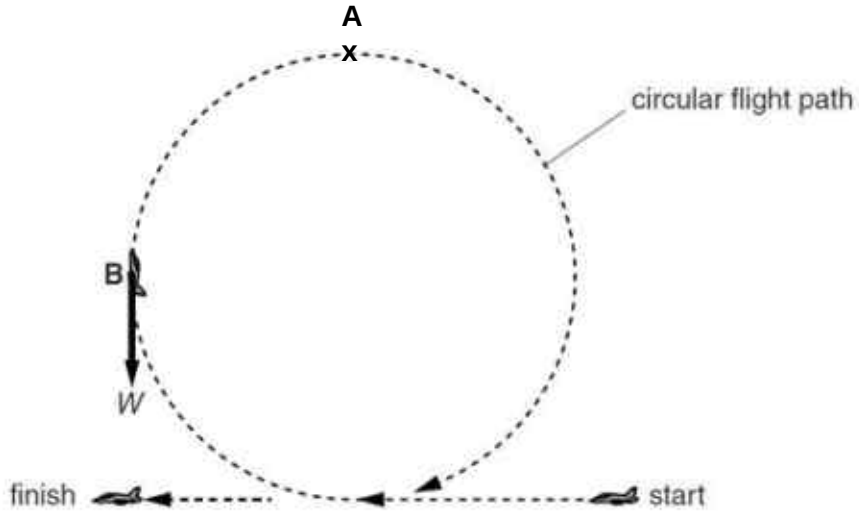


Fig. 6.3

(i) For a certain speed, the pilot can experience a sensation of weightlessness at the highest point **A**.

1 State the magnitude of the vertical component of the contact force exerted by the seat on the pilot at **A**.

contact force = ... N [1]

2 Calculate the speed of the jet at which this occurs.

speed = ... $m\ s^{-1}$ [2]

(ii) At point **B** in Fig. 6.3, the jet is flying vertically upwards.

On Fig 6.3, besides the weight ***W***, draw and label another total force ***P*** acting on the jet at point **B**.

Justify the direction of the force ***P*** that you have drawn.

.....

.....

.....

..... [2]

7 **(a)** State the *principle of superposition*.

.....

.....

..... [2]

(b) Fig. 7.1 shows two small loudspeakers, L_1 and L_2, separated by 15 cm. A microphone M is moved along a line XY parallel to the line joining the two loudspeakers and at a perpendicular distance of 1.5 m away.

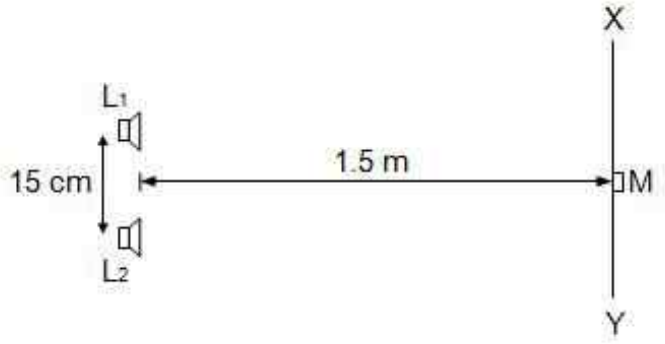


Fig. 7.1

The sound intensity detected by the microphone varies as shown in Fig. 7.2.

X is at the position of 10 cm mark while Y is at the position of 90 cm mark respectively.

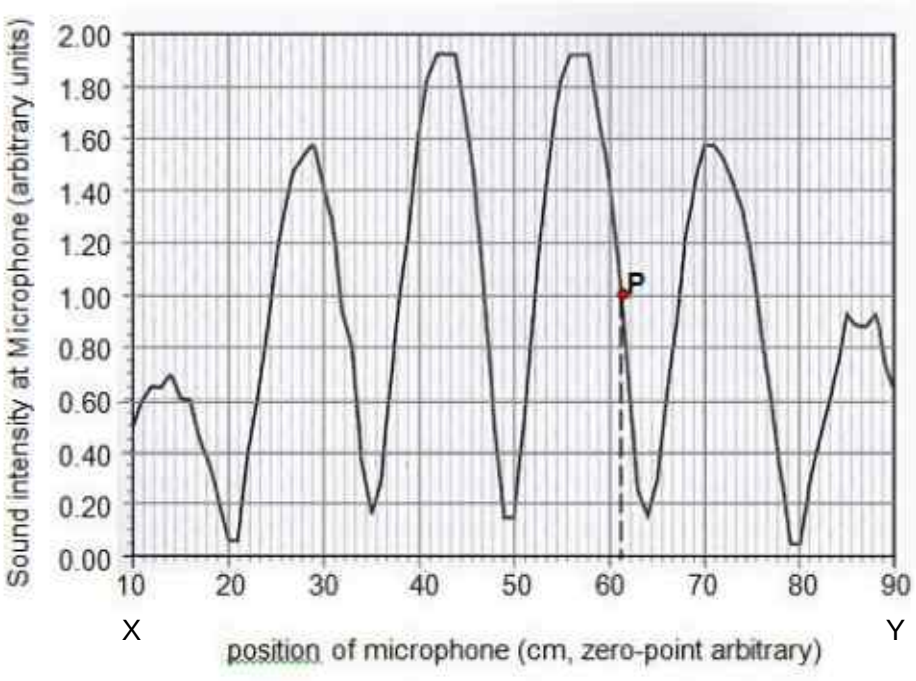


Fig. 7.2

(i) Explain how it can be deduced that the loudspeakers are coherent sources of waves.

.....

..... [1]

(ii) Use Fig. 7.2 to explain that the two sources L_1 and L_2

1. are anti-phase to each other,

..... [1]

2. do not have the same amplitude.

..... [1]

(iii) Given that the speed of sound is 343 m s^{-1}, calculate the frequency of the waves from the loudspeakers.

frequency = ... Hz [3]

(iv) Determine the phase angle between the waves from the loudspeakers when they meet to produce the intensity at point P in Fig. 7.2.

phase angle = rad [3]

(v) Suggest a reason why the maxima on Fig. 7.2 are not all of the same intensity.

.....

..... [1]

(c) White light is incident on a diffraction grating, as shown in Fig. 7.3.

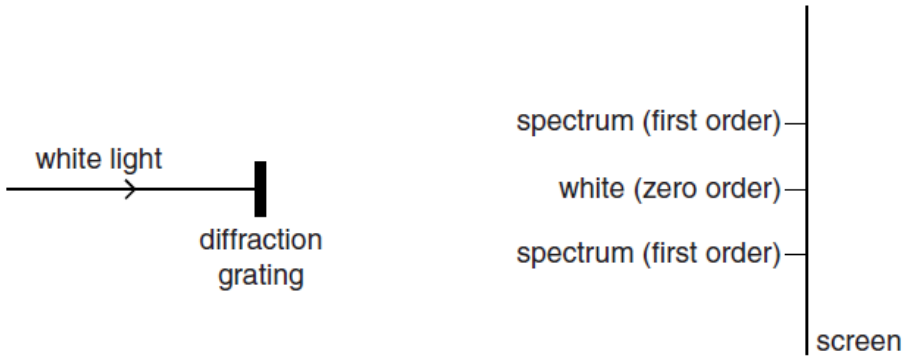


Fig. 7.3

The diffraction pattern formed on the screen consists of a white light band in the zeroth order and coloured spectra in other orders.

(i) Describe how the principle of superposition is used to explain

1. the presence of white light in the zeroth order.

.....

.....

.....

.....

..... [2]

2. the difference in the angular positions of red and blue light in the first-order spectra.

.....

.....

.....

.....

..... [2]

(ii) Light of wavelength 625 nm produces a second-order maximum at an angle of 61.0^{o} to the incident direction.

Determine the number of lines per metre of the diffraction grating.

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

(iii) Calculate the wavelength of another light in the visible spectrum that could produce a maximum at the same angle of 61.0^{o}.

wavelength = ... nm [2]

8 **(a)** Fig. 8.1 shows the three lowest energy levels of a hydrogen atom.

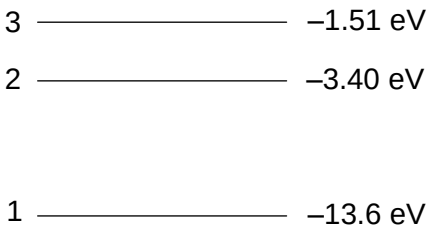


Fig. 8.1

State **two** physical processes by which an electron in the ground state level can move to a higher energy level.

(i) 1. .....

2. ..... [2]

(ii) A parallel beam of white light is incident on a cloud of cool hydrogen gas as shown in Fig. 8.2.

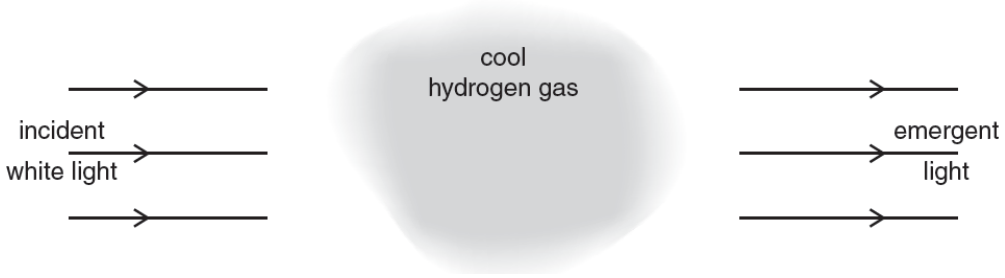


Fig. 8.2

The spectrum of the light emerging from the gas cloud is found to contain a number of dark lines.

One dark line is observed at a wavelength of 658 nm.

1. Calculate the energy, in eV, of a photon of light of wavelength 658 nm.

energy = ... eV [2]

2. Use the energy level diagram in Fig. 8.1 to explain why this dark line occur.

.....

.....

.....

.....

.....

.....

..... [3]

(b) Fig. 8.3 shows an X-ray spectrum obtained when electrons, accelerated from rest through a potential difference of 20 kV, are incident on a heavy metal target.

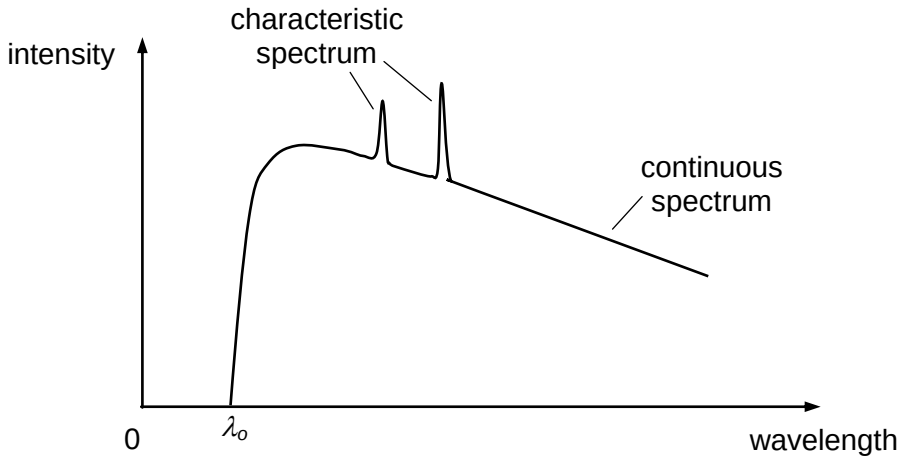


Fig. 8.3

(i) 1. Explain how the *continuous spectrum* of wavelengths is produced.

.....

.....

.....

.....

..... [2]

2. Explain how the *characteristic spectrum* of wavelengths is produced.

.....

.....

.....

.....

.....

.....

.....

[2]

(ii) Calculate the minimum wavelength λ_o of the emitted X-rays.

λ_o = ... m [2]

(iii) The accelerating p.d. applied to the X-ray tube is now increased.

State the change, if any, to

1. the minimum wavelength λ_o ,

.....

[1]

2. the wavelengths of the characteristic lines.

[1]

(iv) The X-ray tube, which is operating at a p.d. of 20 kV, has a current of 60.0 mA.

Only 1.0 % of the electrical power supplied is converted into X-rays.

1. Calculate the power of the X-rays produced.

power = ... W [2]

2. The target in the X-ray tube is made of lead and has a mass of 0.250 kg. The specific heat capacity of lead is 130 J kg^{-1} K^{-1}.

   Calculate the rate at which the temperature of the lead target would rise, assuming that all the wasted energy in the tube is absorbed by the target.

rate of temperature increase = ... K s^{-1} [2]

3. Hence suggest a physical property that a practical target material should have.

..... [1]

2016 Preliminary Examination H2 Paper 1 Solutions:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
D	**A**	**D**	**D**	**B**	**B**	**B**	**A**	**C**	**D**	**A**	**D**	**B**	**D**	**A**	**C**	**B**	**C**	**B**	**D**
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
C	**B**	**C**	**B**	**B**	**C**	**A**	**D**	**D**	**D**	**A**	**B**	**C**	**C**	**D**	**C**	**A**	**B**	**D**	**B**

1 D V_m = volume per unit mol
→ unit of b = unit of V_m = $m^3\ mol^{-1}$

Unit of $[a/V_m^2]$ = unit of P = Pa
→ Unit of a = Pa $(m^3\ mol^{-1})^2$ = Pa $m^6\ mol^{-2}$

2 A
$$g = \frac{4\pi^2 l}{T^2} = \frac{4\pi^2 (0.500)}{(1.42)^2} = 9.789\ \text{m s}^{-2}$$
$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$$
$$\Delta g = \left[\frac{0.001}{0.500} + 2\left(\frac{0.02}{1.42}\right)\right] \text{x} 9.789 = 0.295 = 0.3\ \text{m s}^{-2}\ (\text{to 1 sf})$$
g = (9.8 ± 0.3) m s^{-2}

3 D Taking upwards as positive, since net force is weight downwards, by N2L, acceleration is constant g value, downwards (negative constant value)
At rebound, there is a sharp positive peak as there is sudden impulsive force acting upwards on the ball within a short time of impact
As the ball is moving upwards after rebound, the net force is still weight downwards
→ acceleration is still negative constant value.

4 D For X:
applying $v = u + a\,t$ in the vertical direction:

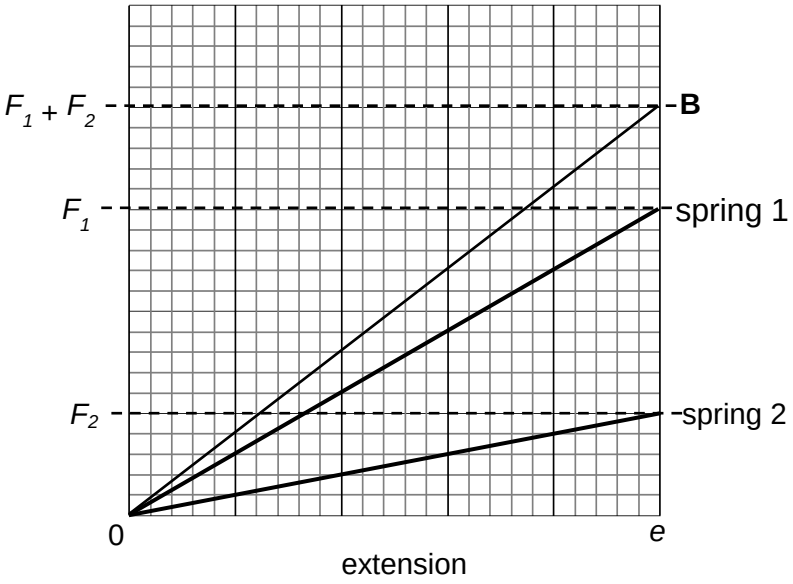
0 = $u \sin\theta - g\,t$ Hence $t = \frac{u\sin\theta}{g}$

Similarly for Y:

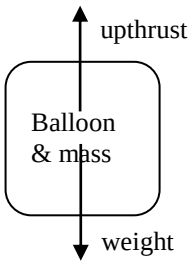
Time to reach max height = $\frac{(2u)\sin\theta}{g} = 2\,t$

Since horizontal velocity for Y is 2 $u \cos\theta$ (or 2 times that of X) and time taken for Y to reach max height is twice that for X, horizontal displacement of Y at max height is 4 times that of X.

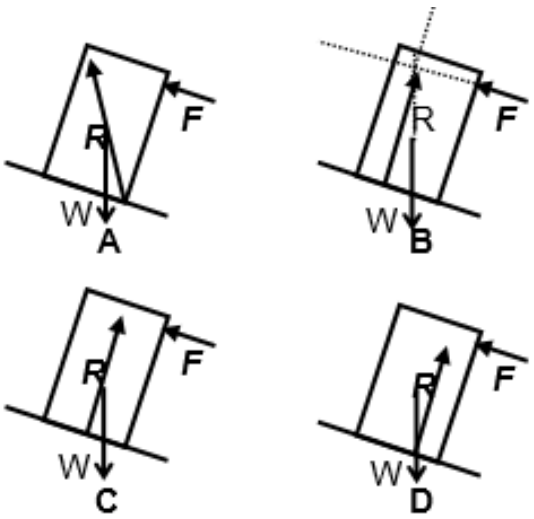
5 B When joined in parallel, both springs would have the same extension, but the applied force would be shared between them. So if the extension is e, spring 1 would be supporting F_1 and spring 2 would be supporting F_2. The applied force is thus $(F_1 + F_2)$.



6 **B** $F = m\,a$
U - mg = 0
U - (80x9.81) = 0
U = weight of displaced air = 80x9.81
$V\,\rho_{air}\,g$ = 80x9.81, so V= 65 m^3



7 **B** The weight of the block has to be included.
Since there are three forces on the block, the forces should be concurrent.



8 **A** The net force is -mgsinθ is a constant. So the net force = rate of change of momentum = slope = constant

9 **C** Use relative speed of approach = relative speed of separation [6-1 = 2-(-3)], as well as conservation of ke.
The incorrect answer A also fulfils the relative speed equation, but because M is heavier, the system seems to have an increase in ke after the collision.

10 **D** Pressure P = hρg, so dP/dh = ρg = 1000x9.81 = 10^4 Pa m^{-1}

11 A at initial angle 45°, the initial horizontal velocity = vertical velocity, i.e. $u_x = u_y$.
at any instant G PE = mgh. Since $h = u_y t - 1/2\ gt^2$, so PE $= mg(u_y t - 1/2\ gt^2)$,
at any instant KE = ½ mv^2 = ½ $m(v_x^2 + v_y^2)$ and $v_y = u_y - gt$,
so KE decrease, then increase quadratically with t.
At maximum height, both KE and PE are equal at ½ mu_x^2

12 D By definition, work done by force F = force F x displacement in the direction of force z

13 B Equation of forces in y and x direction. mg = N , friction $f = mv^2/r$.
=> $\tan\theta = N/f = gr/v^2$, giving $\theta = 36^o$

14 D Gravitational force provides the centripetal force for its circular motion.

$\Rightarrow \quad G\frac{Mm}{r^2} = m\frac{v^2}{r}$

$\Rightarrow$ k.e. $= \frac{1}{2}mv^2 = G\frac{Mm}{2r}$

G.p.e. $= -G\frac{Mm}{r}$

$\therefore$ T.e. = k.e. + G.p.e. $= -G\frac{Mm}{2r}$

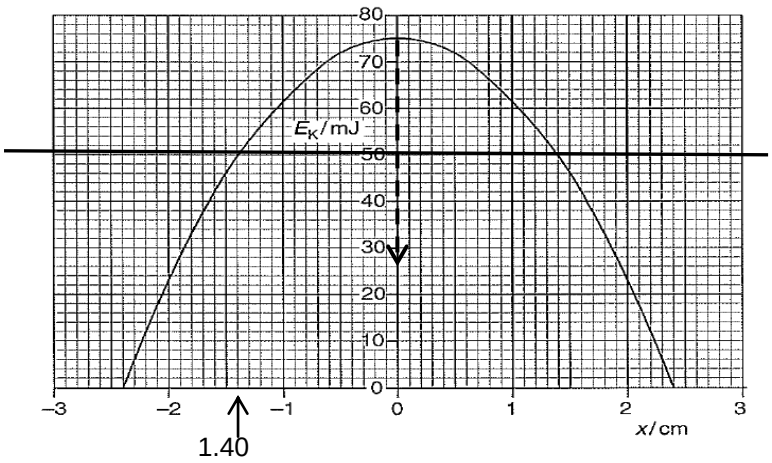
When it goes from low to high orbit, r increases $\Rightarrow$ k.e. ↓, G.p.e ↑ and T.e. ↑

15 A

Resultant field strength $g = \frac{G2M}{d^2} - \frac{GM}{d^2} = \frac{GM}{d^2}$

Resultant potential $\phi = -\frac{G2M}{d} - \frac{GM}{d} = -\frac{3GM}{d}$

16 C <u>First method</u>
Shift the the x-axis up by 50 mJ.
Read off the x value where the curve cuts the x-axis.
x_0 = 1.40 cm



<u>Second method</u>

$KE_{max} = \frac{1}{2}m\omega^2 x_0^{\ 2}$

$KE_{max} \propto x_0^{\ 2}$

$\frac{75}{75-50} = \left(\frac{2.4}{x_0}\right)^2$

$x_0 = 1.39\ \text{cm}$

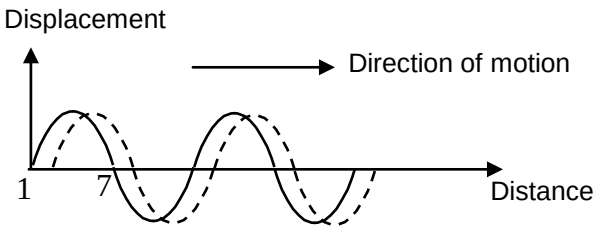
17 B Period of oscillation T = 2 x 0.30 = 0.60 s
Amplitude of oscillation $x_o = \frac{0.36}{2} = 0.18\,m$
Maximum speed of oscillation $= \frac{2\pi}{T}x_o = \frac{2\pi}{0.60} \times 0.18$ = 1.9 m s^{-1}
Taking to the right to be +ve, as particle moves from the amplitude point on the right towards the equilibrium point (ie, x = +ve, v = -ve), speed increases from 0 to 1.9 ms^{-1} for the 1st quarter period. In the next quarter period, it moves from the equilibrium point to the left (x = -ve and v = -ve) with decreasing speed. Hence, as time increases, particle should transverse in the clockwise direction.

18 C Let the final equilibrium temperature be *T*
Heat loss by one = Heat gained by the other
$mc_w(T - T_w) = mc_a(T_a - T)$
$\Rightarrow c_w(T - T_w) = c_a(T_a - T)$
Since $c_w > c_a \Rightarrow (T - T_w) < (T_a - T)$
$\Rightarrow T < \left(\frac{T_w + T_a}{2}\right)$

19 B Since they have the same temperature, average kinetic energy is the same for both since temperature is a measure of the average kinetic energy per molecule.
Iceberg has a greater number of molecules compared to ice cube since it is more massive. Hence its total kinetic energy will be bigger.

20 D Temperature is constant along AB $\Rightarrow P_A V_A = P_B V_B$
Since $P_A > P_B \Rightarrow V_A < V_B \Rightarrow$ work done on gas by surrounding is –ve (non-zero).
Hence option C and D are correct.
From A to B, T = constant $\Rightarrow \Delta U = 0$
Using $\Delta U = Q + W_{on} \Rightarrow Q = -W_{on}$ = +ve $\Rightarrow$ Heat goes into the system.
Hence option D is correct.

21 C Taking to the right to be +ve displacement,



At the next instant of time, particle 1 has –ve displacement (which means it is moving to the left) while particle 7 has +ve displacement (which means it is moving to the right)

22 B Using pythagoras theorem = path length L_2 D = $(40^2+9^2)^{½}$ = 41 m
Path difference between L_1 D and L_2 D = 41 – 40 =1 m

v = fλ
For 1st maximum, path difference = 1λ $\Rightarrow \lambda$ = 1 m
330 = fλ = f(1)
f= 330 Hz

23 C Point X is a node. At one particular instant of time, particles on the left of X will move to the right while particles on the right of X will move to the left, producing a region of compression at X . At another instant of time, particles on the left of X will move to the left while particles on the right of X will move to the right, producing a region of rarefaction at X.

24 B Field lines point from higher to lower potential.
Field lines are closer where the sphere and plate are closer.
Field lines are perpendicular to the equipotential surfaces.

25 **B** Using a positive test charge placed at O, E field components at O point away from J, K and L but towards M. Hence the E field components of J and L cancel each other and net E points towards M.
Magnitude of net E is the vector sum of the E field components from K and M

= 2 ($\frac{q}{4\pi\varepsilon_O r^2}$) where r = ½ (MK) = ½ $(2)^{1/2} x$

26 **C** Power = Energy/time = 120/2.0 = 60 W
A is wrong since current I=P/V = 60/120 = 0.5 A = 0.5 Cs^{-1}
B is wrong since 120 V means 120 J delivered for each Coulomb of charge
D is wrong. It should be 60 J per second when current is 2.0 A

27 **A** When pd is applied across BD,
combined resistance across BD, R_{BD} = 20/3 Ω
When pd is applied across AB,
combined resistance in branches BD and BCD = 20/2 = 10 Ω
Add to branch AD which is in series = 10 + 10 = 20 Ω
Combined resistance across AB = $(1/10 + 1/20)^{-1}$ = 20/3 Ω

This is same as R_{BD} in the previous case.
Since power to circuit, $P = V^2/R$ ➔ $P_{BD} = P_{AB}$

28 **D** Using potential divider concept,
p.d. across the potentiometer wire = E x R/(R + 3R + r)
= ER/ 4R + r
e.m.f. of cell = p.d. across the balance length of wire = L / 3L x (ER/ 4R + r)

$$= \frac{ER}{3(4R + r)}$$

29 **D** Using LHR, for the magnetic force on the wire to be downwards, the magnetic field must be towards the right.

30 **D**

$$B_1(2q)v = \frac{mv^2}{r_1}$$

$$B_2(q)v = \frac{mv^2}{r_2}$$

$$r_2 = \frac{1}{2} r_1$$

$$\therefore B_2 = 4B_1$$

31 **A** Using Flemming's RHR, the direction of the induced emf on PQ is downwards.

32 **B** P to Q: The rod moves parallel to the field, emf = 0
Q to R: The rod moves at angle to the field with constant acc, emf increases at constant rate
After R: The rod moves with free fall, emf is constant as the velocity of the rod perpendicular to the field is constant.

33 C

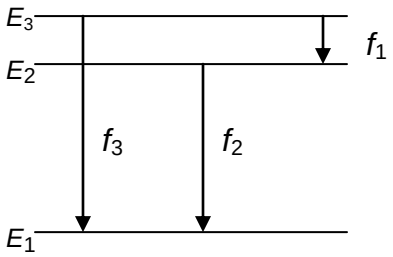
$$I_{rms} = \sqrt{\frac{I_o^{\,2} x \frac{1}{4} T}{T}} = \frac{I_o}{2}$$

34 C $V_s/V_p = N_s/N_p$

35 D $hf = \phi + K$ ……(1)
$h(2f) = \phi + K'$ ……(2)

$2(\phi + K) = \phi + K'$
$K' = \phi + 2K$
$> 2K$

36 C



$E_3 - E_1 = h f_3$; $E_3 - E_2 = h f_1$; $E_2 - E_1 = h f_2$
$E_3 - E_1 = (E_3 - E_2) + (E_2 - E_1)$
$h f_3 = h f_1 + h f_2$

37 A Decrease in electron's KE is transferred to the atom, exciting it. This is subsequently released as a photon when the atom de-excites. Thus $\frac{1}{2} m(u^2 - v^2) = hf$.

38 B Probability of electron tunneling through the barrier and appearing on the other side is smaller, thus reduced amplitude of the wave function on the other side.
PE lower on the other side of the barrier, thus electron emerges with greater KE, since total energy E is constant. Thus momentum increases and the de Broglie wavelength of electron $\lambda = \frac{h}{p}$ decreases.

39 D LHS of equation is the total energy released. This energy manifests as the ke of the products and energy of gamma radiation.

40 B $T_X / T_Y = 1/2 \Rightarrow \lambda_X / \lambda_Y = 2$ (since $T = \ln 2 / \lambda$)
Initially, $A_X = \lambda_X N_X$, $A_Y = \lambda_Y N_Y$

Since $N_X = N_Y$, $A_X / A_Y = \lambda_X / \lambda_Y = 2$
$\Rightarrow A_X = 2A_o/3$, $A_Y = A_o/3$

After 4 days, $A_X' = (1/2)^4 A_X = A_o / 24$
$A_Y' = (1/2)^2 A_Y = A_o / 12$

$A = A_X' + A_Y' = A_o / 8$

Solution to Physics Prelim 2016 H2P2

1 **(a)(i)** $x = 72\ t$ A1

(a)(ii) $y = \frac{1}{2}(9.81)\ t^2$ or $4.91\ t^2$ A1

(b) $100 = 4.91\ t^2$ M1

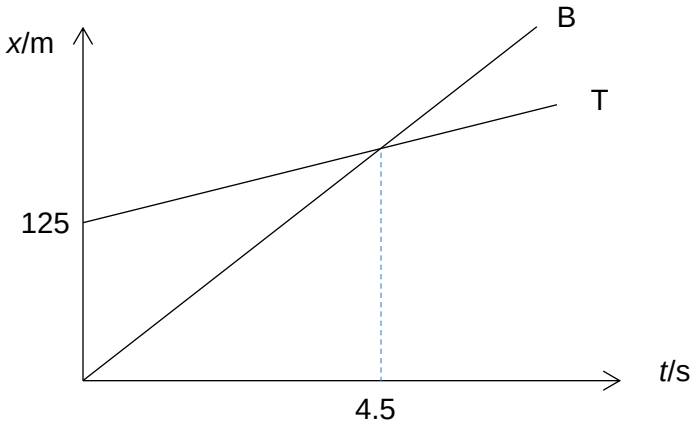
$t = 4.5$ s A1

(c)(i) B1 for each correct graph, must indicate values such as B1

when x = 0, 2 graphs intersect at t = 4.5 s; B1

when t = 0, $x_{bomb} = 0$ and $x_{truck} = 125$ m

No indication of values: deduct 1 mark



(c)(ii) v = gradient of truck graph = [(72 x 4.5) – 125] / [4.5] M1

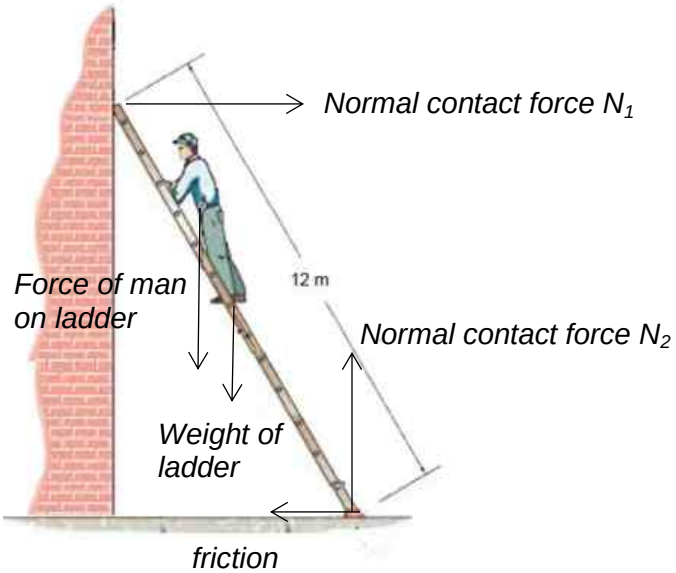
$v = 44$ m s^{-1} (160 km h^{-1}) A1

2 **(a)** Net force in any direction is equal to zero B1

Net torque/moment about any axis is equal to zero B1

(b)(i) Label normal contact force N_1 at wall; normal contact force N_2 at the ground and friction at the ground correctly B1

Label weight of man and weight of ladder correctly B1



(b)(ii) As system is in equilibrium,
$N_2 = (72 + 40) \times 9.81$ M1
$= 1100$ N A1

(b)(iii) $\cos\theta = 6.0/12.0 \rightarrow \theta = 60°$ (or other methods)
Let L be the length of ladder,
Taking moments about D,
$N_1 \sin 60 \times L = (72 \times 9.81 \times \cos 60)(3L/4) + (40 \times 9.81 \cos 60)(L/2)$ M1
$N_1 = 419$ N A1

3 (a) Electrical resistance of a conductor is defined as the ratio of the potential difference across it to the current flowing through it. B1

(b)(i) When S_1 is the only switch closed, lamps A and C are in series giving a resistance of 30.0 Ω. Thus, resistance of a lamp is 30/2 = 15 Ω. B1

Or when all three switches are closed, lamps A and C are in parallel with lamps B and D giving a resistance of 15 Ω. Thus, resistance of a lamp is 30/2=15 Ω.

(ii) faulty lamp: lamp E B1
nature of fault: lamp is short-circuited B1

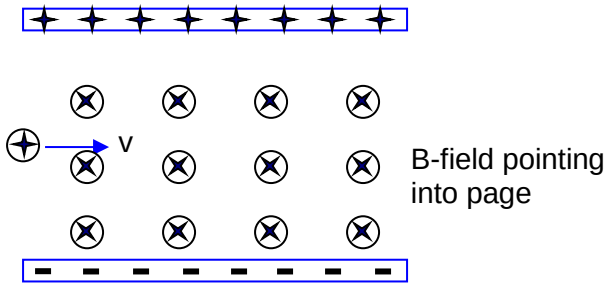
(iii) Short-circuited lamp could cause **excessive current** to flow in the circuit that could cause **damage to the power supply / other lamps / blow fuse in power supply.** B1

(iv)1. Using $V = I R$
$R = V / I$
$= 12.0 / 0.50$
$= 24\ \Omega$ B1

(iv)2. Using $P = V I$ or $I^2 R$ or V^2 / R
$P = 12.0 \times 0.40$
$= 4.8$ W B1

(v) The lamp filament in (iv)1 has a higher resistance than (i) because it is **hotter, or at higher temperature** when operating at normal brightness. B1

4(a) Velocity, E-field and B-field in correct direction (B2 or 0)



B2

(b) For no deflection, $F_B = F_E$

$Bqv = qE = q(V/d)$ M1

$B = V/(dv) = 3000/(0.15 \times 3.7\times10^{6})$

$B = 0.0054$ T or 5.4×10^{-3} T (2 or 3 sf) A1

(c)(i) When the ions enter the region of magnetic field, they experience a magnetic force F_B acting always in a direction perpendicular to their motion or they move in a circular path. B1

Thus $F_B = mv^2/r$

$Bqv = mv^2/r$ M0

$r = mv/Bq$ A1

Since they should have the same v, B and have the same charge, the radius of path is dependent on their mass. i.e.r α M . Thus they can be differentiated. B1

(ii) Semicircle, entering detector 1 B1

5 **(a)** *Population inversion* is a condition whereby there are more atoms in an excited state than in the ground state. B1

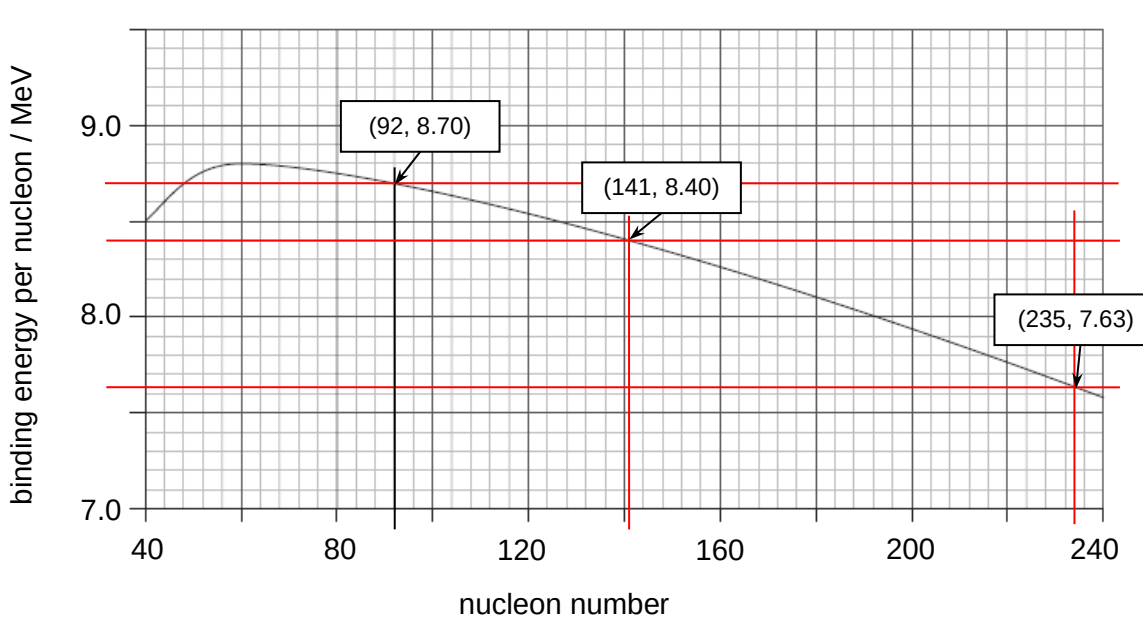
(b) At thermal equilibrium, the lower energy state is more populated than the higher energy state. To achieve population inversion therefore requires supplying energy to excite more atoms to the excited level with respect to the ground level. B1

(c) For a 2-level system optically-pumped, the pump radiation can be absorbed, populating the upper lasing level. But the pump radiation can also stimulate emission, reducing the population in the upper laser level. Hence in steady-state, population inversion can never be achieved. B1

(d) The intermediate level must have a metastable state, i.e. has a **relatively longer lifetime** for excited atoms to decay to the ground state. (Just stating metastable is insufficient). B1

This allows excited atoms to accumulate at this level, thus achieving population inversion with respect to the ground. B1

6



6 **(a)** *Binding energy* is the energy released when the nucleus is formed from its separate proton and neutrons,
or
it is the energy required to break up the nucleus into separate nucleons. B1

(b) **(i)** $x = 2$ B1

(ii) U-235 binding energy per nucleon = 7.63 MeV (accept 7.65)
Kr binding energy per nucleon = 8.70 MeV
Ba binding energy per nucleon = 8.40 MeV M2

Total U-235 binding energy = 7.63 x 235 = 1793 MeV
Total Kr and Ba binding energy = (141 x 8.40) + (92 x 8.70) = 1985 MeV M1

energy released = 1985 – 1793 = 192 MeV ≈ 190 MeV M1

(iii) Number of U-235 nuclei required $= \dfrac{1.0 \times 10^{3}}{190 x 1.60 \times 10^{-13}}$ M1
$= 3.2 \times 10^{13}$ A1

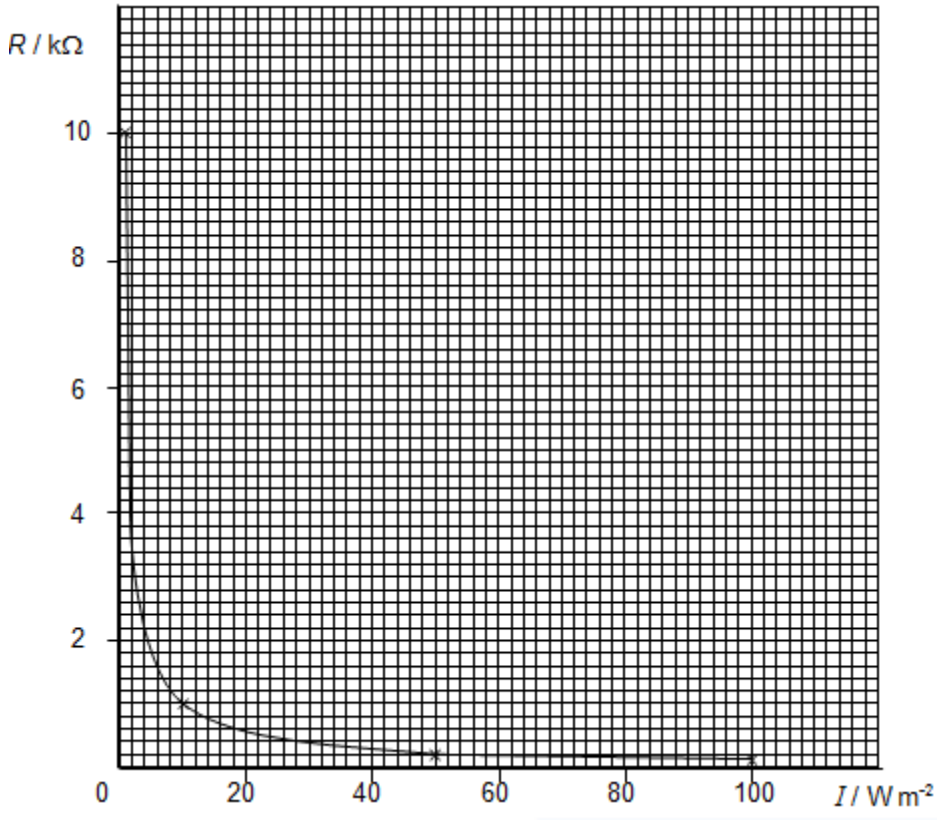
(iv) Energy released is carried away as kinetic energies of the product particles B1

7 **(a)(i)** resistance of LDR = 0.20 kΩ B1

(ii) A logarithmic scale compresses the scale so that the widely differing values can be shown easily on one graph. B1

(iii) On the logarithmic scale in Fig. 7.1, the graph is similar to lg R against lg I. B2
It is a straight line with gradient = -1 and value of R at A is 10kΩ, the relation is true.

(b) 4 Points plotted correctly. B2
Draw a best fit curve.



(c)(i) $I \geq 50.0 Wm^{-2} \Rightarrow R_{LDR} \leq 0.2k\Omega$ B1
When R_{LDR} = 0.2 kΩ
$V_R = \frac{R}{R+R_{LDR}} \times 12 = 9$ M1
R = 0.60 kΩ A1

(ii) It can be used as a burglar alarm. The LDR can be attached to the door such that it is covered when the door is closed. When a burglar opens the door, the surrounding light will fall on the LDR causing its resistance to drop, thus resulting in a rise in p.d. across the variable resistor and buzzer. The buzzer will sound when the p.d. across it rises above 9 V. B2

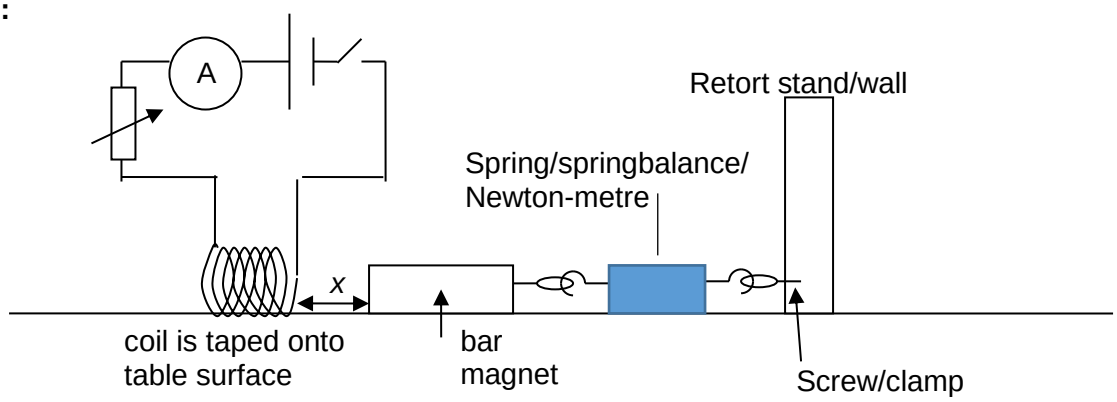
(iii) Below 1 W m^{-2}, the LDR's resistance changes too rapidly with intensity such that any small fluctuation in intensity will cause a trigger. B2

(iv) 1. Connect buzzer across LDR B1
2. Replace LDR by a thermistor (whose resistance decreases as temperature increases) B1

Suggested mark scheme for Question 8 Planning Qn

Defining the problem	
– Independent variable: distance *x* between closest ends of coil and magnet	1
– Dependent variable: attractive force *F* between coil and magnet	
– Control of variables: use constant current in coil(most impt)+use the same bar magnet, no other magnetic fields present	1
Method of data collection	
– Fully-labelled diagram including circuit diagram to provide current to coil and workable arrangement to bar magnet to measure *x*.	1
– Method of measuring *x* using metre rule.(take note x is the final closest distance between bar magnet, not the initial distance)	1
– Method of measuring force *F* between magnet and coil using spring/spring balance/ Newton-meter/force sensor connected to data logger. (Allow measurement of angle of swing of a suspended magnet)	1
– Method to ensure the force is attractive, e.g. ensure unlike poles facing	1
– Method of keeping current in coil constant (read ammeter reading)	1
– Some details on how to vary *x*, e.g. moving bar magnet away from coil and keeping coil fixed in position	1
Method of analysis	
– Suggest an appropriate graph. Assume $F = kx^n \Rightarrow lg\ F = n\ lgx + lgk.$ Plot *lgF* vs *lgx* where gradient and intercept of graph give *n* and lg*k* respectively	1
Safety considerations	
– Handle hot wire with care/ Switch off the circuits when not in use to prevent over heating	1
– Avoid injury by staying at safe distance from extended spring and hot wire.	
Additional details (any two)	
– Details on how to increase the current/change to lower spring constant so that the force or extension of the spring is measurable. .	2
– Determine spring constant *k (* suspend the spring vertically from a retort stand, attach a mass m to it and measure its extension *e, then calculate k = mg/e)*	
– Method to align the apparatus in a straight line/secure the coil and spring on table.	
– Repeat the measurement of *F* for each *x* and obtain the average to reduce random error/Repeat the experiment by increasing then decreasing *x* to ensure reliability	
– Ensure that the spring is not permanently deformed.	
– Conduct a trial experiment to establish a suitable measurable range of x and *F*	
– Lubricate surface to ensure minimum friction.	
Total	12

Diagram:



Solution to Physics Prelim 2016 H2P3

Section A

1 **(a)** work done per unit mass to bring a mass from infinity to the point. B1

(b) recognize that potential energy of particle decreases from M_2 to M_1 ; M1
therefore by COE, a gain in KE and hence KE is larger A1

(c) x = 4.8 x10^9 m; (allow answers in the range of 4.5 to 5.0) A1
this corresponds to the point where the gradient dV/dr (= g) is zero M1

(d) field strength due to M_1 = field strength due to M_2 at 4.8 x10^9 m

$$\frac{GM_1}{r_1^{\,2}} = \frac{GM_2}{r_2^{\,2}}$$

$$\frac{M_1}{4.8^2} = \frac{M_2}{7.2^2}$$ M1

$$\frac{M_1}{M_2} = 0.44$$ A1

(allow answers in the range of 0.36 to 0.48)

2 **(a)** The increase in internal energy of a system is the sum of the work done on the system and the heat absorbed by the system B1

(b) Maximum temperature is at V = 5.0 x 10^{-3} m^3 and P = 9.0 x 10^5 Pa B1

$$T = \frac{PV}{nR} = \frac{9.0\times10^5\times5.0\times10^{-3}}{0.74\times8.3}$$

= 733 K A1

(c) Work done by the gas = Area under the graph from A to B
= (5.0 – 2.0) x 10^{-3} x 9.0 x 10^5 M1
= 2700 J A0

(d) $\Delta U \propto \Delta T$. Since $\Delta T = 0$ for the cycle $\Rightarrow$ $\Delta U = 0$ J B1

(e) Work done by gas from A$\rightarrow$B is greater than work done on gas from C$\rightarrow$A
$\Rightarrow$ net work done is by the gas, hence W_{on} = -ve C1
Using $\Delta U = Q + W_{on}$, since $\Delta U = 0$ J from (d) $\Rightarrow$ $Q = -W_{on}$ = +ve.
Hence, heat is absorbed in the cycle A1

3 **(a)1** $gradient = -\omega^2 = -\left(\frac{2\pi}{T}\right)^2 = -\frac{4\pi^2}{T^2}$ M1

$\Rightarrow \frac{1.0-(-1.0)}{-0.028-0.028} = -\frac{4\pi^2}{T^2}$ C1

$\Rightarrow$ T = 1.05 s A0

(a)2 $E_{max} = \frac{1}{2}mw^2x_o^2 = \frac{1}{2} \times 0.20 \times \left(\frac{2\pi}{1.05}\right)^2 \times 0.024^2$ M1

= 2.06 x 10^{-3} = 2.06 mJ A1

(b) Taking upwards as +ve,

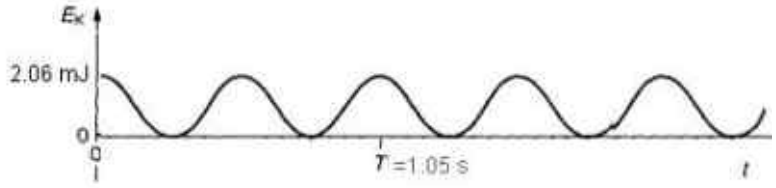
$x = x_o sin\omega t$ M1

$\Rightarrow 1.5 = 2.4sin\left(\frac{2\pi}{1.05}t\right)$

$\Rightarrow$ t = 0.113 s A1

(c) cosine^2 graph with 5 peaks. B1

Period = 1.05 s, and maximum kinetic energy = 2.06 mJ labelled B1



4 **(a)** Electric potential at a point is the work done per unit positive charge by an external agent in bringing a charged body from infinity to that point B1

(b) **(i)** $W_{AB} = 5.00 \times 10^{-7} \times 2.0 \times 10^{-2} = 1.0 \times 10^{-8}$ J A1

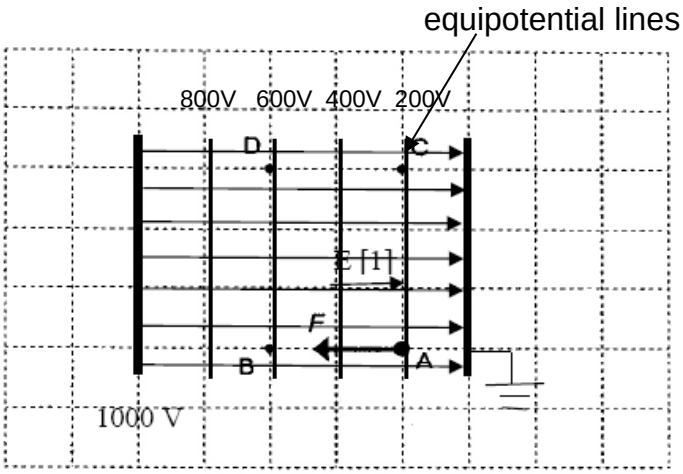
(ii) $W_{AC} = 0$ J A1

(iii) $W_{AD} = 1.0 \times 10^{-8}$ J A1

(c) $V_{AB} = W_{AB} / Q = 1.00 \times 10^{-8} / 2.50 \times 10^{-11} = 400$ V
$V_{AB} = V_B - V_A$ M1
$400 = V_B - 200 \Rightarrow V_B = 600$ V A1

(d) See diagram in (e) below.
Correct position of earthed plate is earthed and the other plate at 1000 V. B1
Correct spacing of 5.0 cm between plates B1

(e) Correct sketch of 4 equally spaced equipotential lines B1
Correct labelling of lines at 800 V, 600 V, 400 V and 200 V B1



5 **(a)** As rods AB and CD are made to move across a region of magnetic flux density B, there is a change in flux linkage with the area. B1

An e.m.f. is induced between the ends of the rods according to the Faraday's law of electromagnetic induction. B1

(b) e.m.f. induced = $|-\frac{d\Phi}{dt}|$ = $B\frac{dA}{dt}$ = (0.20)(0.15)(5.0 – (-3.0)) M1

= 0.24 V A1

(c) Because the area is increasing, the flux linkage is increasing. By Lenz's law, the induced current in the loop will tend to create a magnetic field to oppose the applied magnetic field. B1

By the right hand grip rule, the induced current will flow in the anticlockwise direction of ABDCA. B1

OR

For rod AB, by Fleming's right hand rule, the induced current will flow from A to B.
Similarly, for rod CD moving at a larger speed, a larger induced current will flow from D to C.
Hence, the net induced current will flow in the anticlockwise direction of ABDCA.

(d) The rate of increase of area (dA/dt) is now of a smaller magnitude. B1

Hence by Faraday's law, the induced e.m.f. will have a smaller magnitude as well. B1

OR

The induced current due to the motion of rod AB will now flow from B to A, opposing the current induced by the motion of rod CD. The currents will partially cancel, thus the induced e.m.f. will be smaller.

Section B

6 **(a)** Force is equal to the rate of change of momentum of a body. B1

(b) **(i)** $a = F / m$

a = 28 x 103 / 6200 (= 4.52 ms^{-2}) C1

$v^2 = u^2 + 2as$ M1

$56^2 = 0 + 2 \times 4.52s$

s = 347 or 350 m A1

(ii) Air resistance/drag/friction acts on aircraft decreasing the net forward force **/** acceleration C1

Since $v^2 = (u^2) + 2as$ so reduced acceleration means longer distance to reach take-off speed. **OR** A1

Work done by thrust = Fs = change in KE so reduced force must act over a longer distance to produce enough kinetic energy for take-off.

Since $v^2 = (u^2) + 2as$ so reduced acceleration means longer distance to reach take-off speed.

(iii) As the speed increases, viscous drag increases until it is equal to the forward engine thrust. C1

So finally, net force/acceleration is zero, so jet reaches its terminal velocity. A1

(c) **(i)** the horizontal component of the Lift L is able to provide the centripetal force for circular motion. The vertical component of L balances the weight to maintain constant height. B2

(ii) $L \cos 35^o = W$ M1

= 6200 x 9.81 A0

L = 74000N

(iii) $L \sin 35^o = mv^2/r$

r = $6200 \times 86^2 / 740000$ M1

= 1100 m A1

(iv) Larger circle requires a smaller centripetal force($F = mv^2/r$), M1

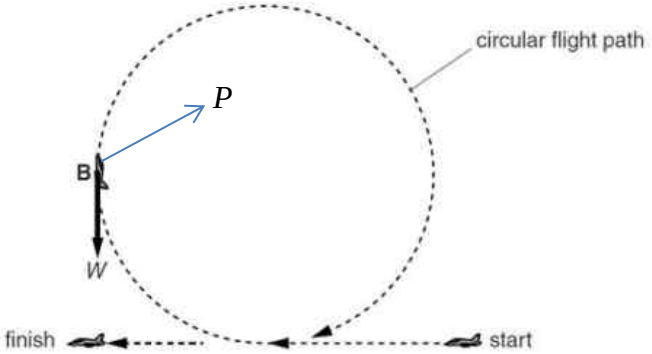
so smaller horizontal component of L needed, hence θ can be less than 35°. A1

(d) **(i)** 1. Contact force = 0 N A1

2. $mg = mv^2/r$, M1

so $v = (gr)^{1/2} = 48.5\ ms^{-1}$ A1

(ii) P is drawn at an angle from the vertical. B1



B1

Horizontal component of *P* must be towards centre of circle/provide centripetal force
Or the resultant of P and W must provide centripetal force at B.

7 **(a)** When **two or more waves** of the **same kind** exist simultaneously at a point in space, the **resultant displacement** of the waves at a point is the **vector sum** of the **displacement due to each wave** acting independently. B2

(b) **(i)** Since a well-formed interference pattern is obtained, the two sources are coherent (because this is one of the conditions to obtain a well-formed interference pattern). B1

(ii) 1. There is minimum intensity at position M or at 50 cm. B1

2. The pattern has non-zero minima. B1

(iii) Using $\frac{\lambda}{d} = \frac{\Delta x}{D}$ M1

$\Rightarrow \lambda = \frac{60\ cm}{4} \times \frac{15\ cm}{150\ cm}$ C1

$\therefore\ f = \frac{v}{\lambda} = \frac{343}{0.015} = 2.3 \times 10^4$ Hz A1

(iv) Using $\frac{\phi}{2\pi} = \frac{12\ cm}{15\ cm}$ M1

$\Rightarrow\ \phi = 1.6\ \pi$ rad C1

Since the waves are initially π radians out of phase, the total phase difference is $1.6\pi + \pi = 2.6\ \pi \equiv 0.6\ \pi$ rad or 1.9 rad. A1

(v) At higher orders. the 2 waves travel longer path lengths/distances before superposing. B1
Since amplitude decreases with distance, the intensity of the maxima formed at higher orders are lower than the zeroth order.

(c) **(i)** 1. Each of the wavelengths in the white light travels the same path difference or arrive in phase at the zeroth order B1
The maxima mix/add up to produce a resultant white colour B1

2. wavelength λ of red light > wavelength blue light ($\lambda_{red} > \lambda_{blue}$) B1
To produce a maxima for 1st order, $d\sin\theta = 1\ \lambda$ B1
Hence, maxima for both colors occurs at different angle θ A0

(ii) $d\sin\theta = n\lambda\ \ or\ \frac{1}{N}\sin\theta = n\lambda$ C1

$\Rightarrow N = \frac{\sin 61^o}{2 \times 625 \times 10^{-9}}$

$= 7.0 \times 10^5$ m^{-1} A1

(iii) $n\lambda$ = 2 x 625 = 1250 = constant C1

$n = 1 \Rightarrow \lambda = 1250$ nm (outside visible region)

$n = 3 \Rightarrow \lambda = 417$ nm (inside visible region)

$n = 4 \Rightarrow \lambda = 312.5$ nm (outside visible region)

Hence, $\lambda = 417$ nm A1

8 **(a)** **(i)** Any 2 of the following B2

- collisions with external particles
- heating the gas to a high temperature
- absorption of photons

(ii) 1. $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{658 \times 10^{-9}}$ J M1

$= 1.89$ eV A1

2. Electrons absorb photons of energy 1.89 eV to make a transition from n=2 to n=3. C1

On de-excitation, photons of energy 1.89 eV, i.e. wavelength 658 nm are emitted. M1

But photons emitted are <u>in all directions, not just along the initial direction</u>, hence intensity is reduced. A1

(b) **(i)** 1. Electrons suffer <u>rapid decelerations</u> upon hitting target, and emit X-rays. B2

The <u>decelerations of the electrons have a range of values</u>, thus leading to radiation with <u>a range of wavelengths</u>.

2. <u>Incident electron knock out inner shell electron of target metal atom</u>, leaving vacancy. B2

<u>Outer shell electron of target metal atom transit down to fill vacancy, producing an X-ray photon</u> of energy equal to the difference in energies of the 2 shells.

(ii) $eV = \frac{hc}{\lambda_o}$

$\lambda_o = \frac{hc}{eV} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{(1.6 \times 10^{-19})(20 \times 10^{3})}$ M1

$= 6.2 \times 10^{-11}$ m A1

(iii) 1. the minimum wavelength λ_o shifts to the left A1

2. the positions of the characteristic lines remains unchanged A1

(iv) 1. $P = (\frac{1.0}{100})VI = (\frac{1.0}{100})(20.0 \times 10^{3})(60.0 \times 10^{-3})$ M1

$= 12$ W A1

2. $Q = mc\Delta\theta$

$\Delta\theta = \frac{Q}{mc} = \frac{(0.99)(20.0 \times 10^{3})(60.0 \times 10^{-3})}{(0.250)(130)}$ M1

$= 36.6 \ or \ 37$ K s^{-1} A1

3. Target material should have
a high melting point ,or large specific heat capacity A1

VICTORIA JUNIOR COLLEGE
2016 JC2 PRELIMINARY EXAMINATIONS

PHYSICS
Higher 2

9646/01
22 Sep 2016
Thursday

Paper 1 Multiple Choice

1 Hour 15 min

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, CT group and index number on the 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 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.

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}

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, $p = h\rho g$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm\omega\sqrt{(x_o^2 - x^2)}$

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, $x = x_o \sin \omega t$

transmission coefficient, $T = \exp(-2kd)$
where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 A power station generates power of 3.0 GW. What is the energy produced for a time interval of 2.0 ps?

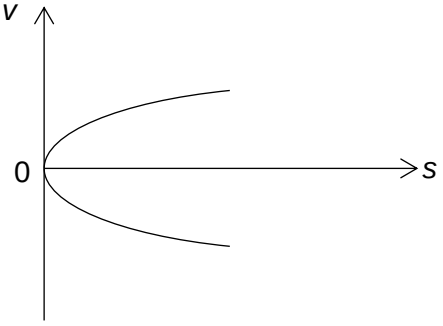
A 6.0×10^{-15} TJ **B** 6.0×10^{-6} MJ
C 6.0×10^{3} nJ **D** 6.0×10^{6} μJ

2 Ah Seng wanted to measure the period of a pendulum, but he did not have a stopwatch. So he used a wall clock instead. He noted the start time for 20 oscillations to be (12.0 ± 0.5) s, and the stop time to be (57.0 ± 0.5) s. What is the period of the pendulum?

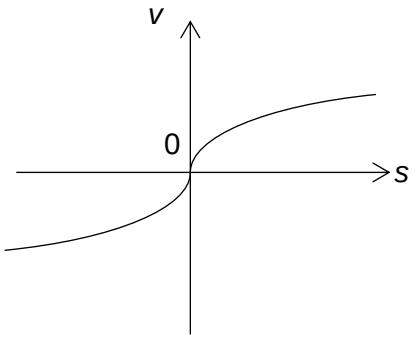
A (2.25 ± 0.03) s **B** (2.25 ± 0.05) s
C (2.3 ± 0.5) s **D** (2 ± 1) s

3 A ball is released from point P, and bounces once on the floor. Which of the following graphs correctly shows how its velocity *v* varies with displacement *s* with respect to P?

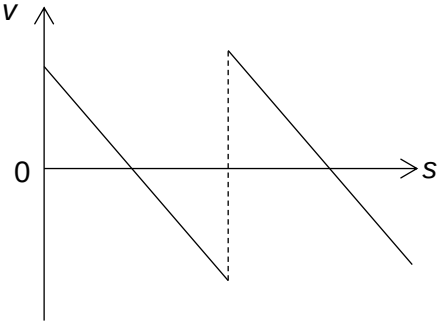
A



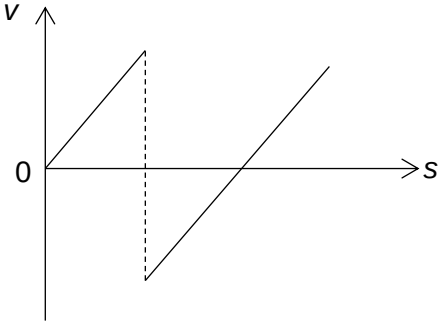
B



C



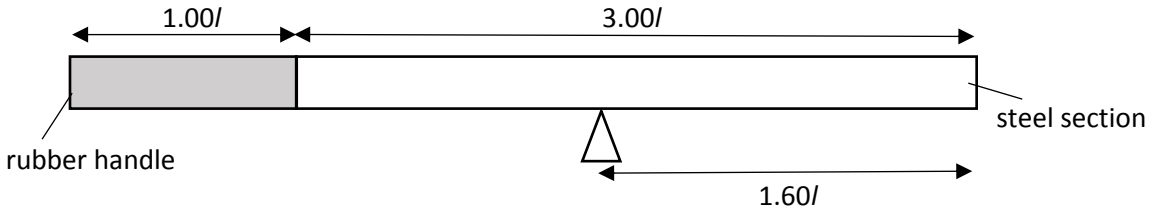
D



4 A stone is thrown at a velocity of 12 m s^{-1} at an angle of 25° above the horizontal. What is the magnitude of the change in velocity from its starting point to the highest point in its path?

A 1.1 m s^{-1} **B** 5.1 m s^{-1} **C** 5.8 m s^{-1} **D** 12 m s^{-1}

5 A uniform rod has a steel section and a solid rubber handle, as shown.

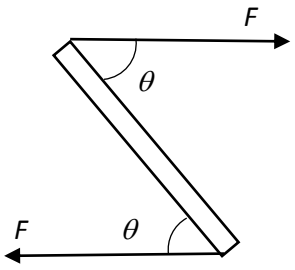


The length of the handle is *l* and the length of the steel section is 3.00*l*. The rod balances a distance 1.60*l* from the steel end.

What is the $\frac{\text{density of steel}}{\text{density of rubber}}$?

A 0.158 **B** 1.90 **C** 3.00 **D** 6.33

6 Equal and opposite forces of magnitude *F* are applied to the ends of a ruler of length *L*, creating a couple as shown in the diagram.



What is the torque of the couple on the ruler when it is in the position shown?

A $FL\cos\theta$
B $FL\sin\theta$
C $2FL\cos\theta$
D $2FL\sin\theta$

7 Particle X has a mass m and particle Y has a mass $3m$. They travel at equal speed v but in opposite direction along a smooth horizontal surface, and then collide head-on elastically.

Which of the following statements is false?

A The total kinetic energy of the system consisting of the two particles is not conserved throughout the duration of the collision.

B The total energy of the system consisting of the two particles is conserved throughout the duration of the collision.

C The total momentum of the system consisting of the two particles is always conserved except during time of collision due to the presence of collision forces between the two particles.

D The relative speed of separation after the collision is $2v$.

8 The graph in Fig 8 shows how the force F acting on a car varies with time t while it is traveling for 50 s. The mass of the car is 1000 kg.

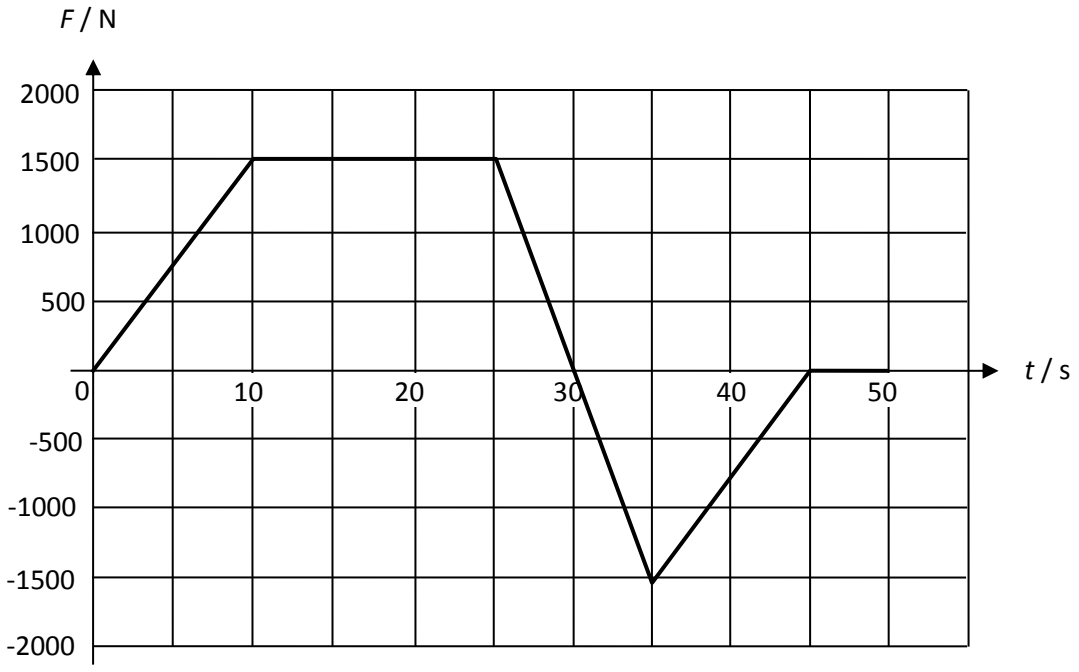


Fig 8

What is the velocity of the car at t = 50 s if it had an initial velocity of 10 m s^{-1} at t = 0 s?

A 10.8 m s^{-1}
B 22.5 m s^{-1}
C 32.5 m s^{-1}
D 55.0 m s^{-1}

9 An object of weight 50 N is dragged up an inclined plane at constant speed of 5.0 m s^{-1}, through a vertical height of 12 m. The total work done is 1500 J.

The work done against friction is

A 600 J **B** 840 J **C** 900 J **D** 1500 J

10 A speed-boat with two engines, each of power output 30 kW, can travel at a maximum speed of 10 m s^{-1}. The total drag D on the boat is related to the speed v of the boat by the equation shown.

$$D \propto v^2$$

What is the maximum speed of the boat when only one engine is working?

A 2.5 m s^{-1} **B** 5.0 m s^{-1} **C** 7.1 m s^{-1} **D** 7.9 m s^{-1}

11 A car of mass 1400 kg goes over a large semi-circular road hump of radius 9.0 m. At the top of the hump, its speed is 30 km h^{-1}. What is the force that it exerts on the road?

A 2.9 x 10^3 N **B** 1.1 x 10^4 N
C 1.4 x 10^4 N **D** 2.5 x 10^4 N

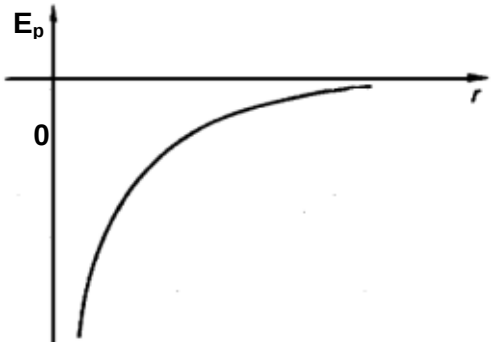
12 An aeroplane flies at a speed of 520 km h^{-1} in a horizontal circle of radius 360 m. By how much must it tilt its wings from the horizontal?

A 0° **B** 9.6^o **C** 80° **D** 90°

13 The escape speed of an oxygen molecule at the Earth's surface is 1.1×10^4 m s^{-1}. What is its escape speed at a height 0.2 R_E above the Earth's surface, where R_E is the radius of the Earth?

A 0.50×10^4 m s^{-1}
B 1.0×10^4 m s^{-1}
C 1.2×10^4 m s^{-1}
D 2.5×10^4 m s^{-1}

14 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 acceleration of the body towards the planet
B the force pulling the body towards the planet
C the gravitational field strength at that value of *r*
D the gravitational potential at that value of *r*

15 A particle oscillates with simple harmonic motion at a frequency, *f*. What is the frequency at which the kinetic energy of the particle varies?

A $\frac{f}{2}$ **B** f **C** $2f$ **D** f^2

16 An object placed on a horizontal platform is oscillating vertically in simple harmonic motion with a frequency of 1.5 Hz. What is the maximum amplitude of oscillation that will allow the object to remain in contact with the platform throughout the motion?

A 0.11 m **B** 1.0 m **C** 6.5 m **D** 9.0 m

17 A hot water tank of heat capacity 5000 J K^{-1} contains 5.0 kg of water at 30 °C. What is the time taken to raise the temperature of the water to 45 °C using a heater coil of power of 2.5 kW, given that the specific heat capacity of water is 4200 J kg^{-1} K^{-1}?

A 156 s **B** 256 s **C** 276 s **D** 468 s

18 The temperature of 1 kg of hydrogen gas is the same as that of 1 kg of helium gas. Which of the following statements is correct?

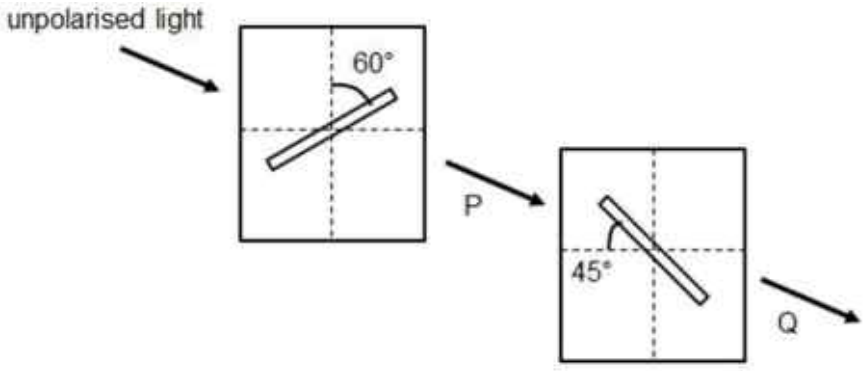
A The gases have the same internal energy.

B The gas molecules occupy equal volumes.

C The gas molecules have the same root mean square speed.

D The gas molecules have the same mean translational kinetic energy.

19 A beam of unpolarised light with amplitude *A* and intensity *I* is passed through two optical polarisers. The first polariser's transmission axis is oriented at 60° to the vertical, while the second polariser's transmission axis is oriented at 45° to the horizontal.



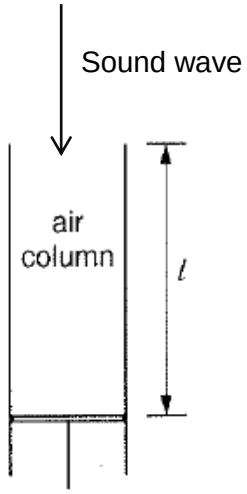
What is the intensity of the light at P and amplitude of the light at Q?

	Intensity of light at P	**Amplitude of light at Q**
A	$\frac{1}{\sqrt{2}}I$	$\frac{1}{2}A\sin 15^\circ$
B	$\frac{1}{\sqrt{2}}I$	$\frac{1}{2}A\cos 15^\circ$
C	$\frac{1}{2}I$	$\frac{1}{\sqrt{2}}A\cos 15^\circ$
D	$\frac{1}{2}I$	$\frac{1}{\sqrt{2}}A\sin 15^\circ$

20 A point source of sound emits energy equally in all directions at a constant rate and a detector placed 3.0 m from the source measures an intensity of 5.0 W m^{-2}. The amplitude at the source is then doubled. What intensity, in W m^{-2}, would the detector measure if it is now placed at a distance 4.0 m from the source?

A 0.45 **B** 0.56 **C** 11 **D** 15

21 A sound wave of constant wavelength is continuously transmitted into an air column. The length *l* of the air column is slowly increased from zero.

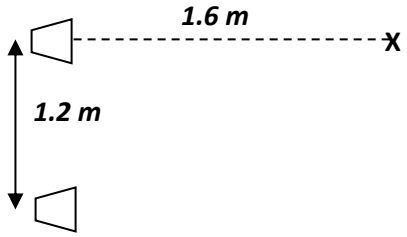


When *l* reaches certain values, the sound heard from the air column increases greatly in volume. *l* is found to be 15 cm when the sound increases greatly for the third time.

What is the wavelength of the sound wave?

A 7.5 cm **B** 10 cm **C** 12 cm **D** 20 cm

22 Two loudspeakers are placed 1.2 m apart as shown below. Both speakers are operating in phase and are giving out a steady frequency of 400 Hz. Point X is 1.6 m from one speaker. The speed of sound can be taken as 320 ms^{-1}



Which of the following is correct about point X?

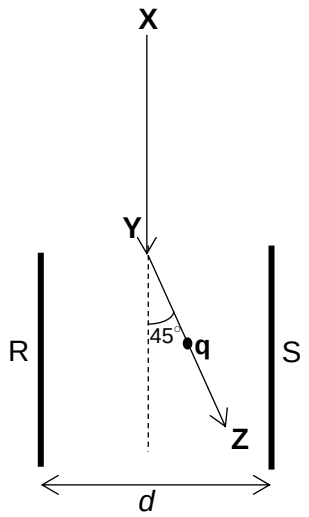
A It has maximum intensity.

B It has intensity between minimum and maximum.

C It has minimum intensity.

D It has intensity that varies from minimum to maximum periodically.

23 A sphere carrying a charge q and having a weight W falls under gravity along XY. At Y, it enters a pair of parallel plates R and S separated by a distance d. At that moment, a potential difference V is applied between the plates, and the path of the sphere changes to YZ as shown in figure below.



The value of the charge q is

A W/V

B $W/2V$

C Wd/V

D $Wd/2V$

24 Which of the following statements about an electric field is **incorrect**?

A The electric field strength due to a point charge varies as $1/r^2$ where r is the distance from the charge.

B The electric field strength at a point is a measure of the force exerted on a unit positive charge at that point.

C The electric field strength is zero at all points where the potential is zero.

D The electric field strength at a point is a measure of the potential gradient at that point.

25 The electrical potential difference between two points in a wire carrying a current may be defined as

A the product of the current squared and the resistance between the two points.

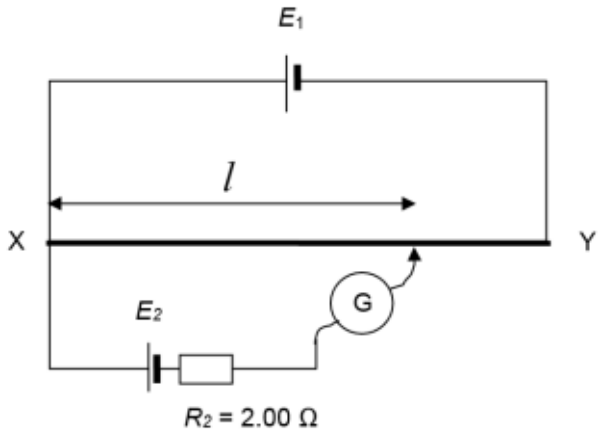
B the ratio of the energy expended to the current between the points.

C the ratio of the power supplied to the current between the points.

D the ratio of the power supplied to the charge moved between the points.

26 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.

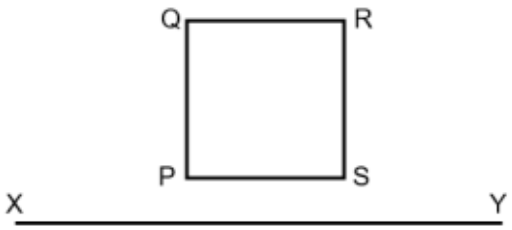
Another battery E_2 is connected to X and it is in series with a 2.00 Ω resistor and a galvanometer. The balance length l is found to be 0.745 m.



What is the e.m.f. of E_2?

A 0.636 V **B** 2.72 V **C** 5.73 V **D** 9.00 V

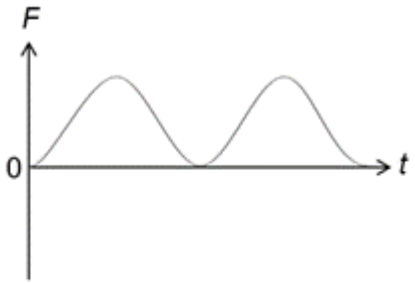
27 A long straight wire XY lies in the same plane as a square loop of wire PQRS which is free to move. The sides PS and QR are parallel to XY.



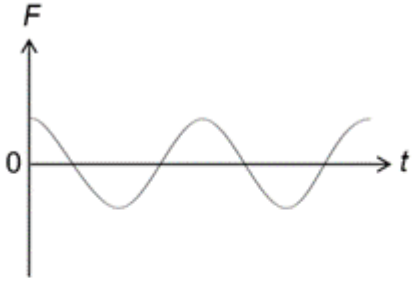
Both the wire and loop carry equal sinusoidal alternating currents. The currents in XY and side QR differ in phase by π rad.

Which one of the following graphs shows the variation with time *t* of the *resultant force of attraction F* between the wire and the loop?

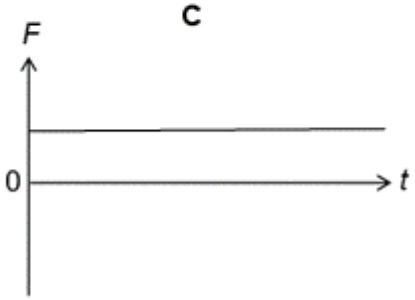
A



B



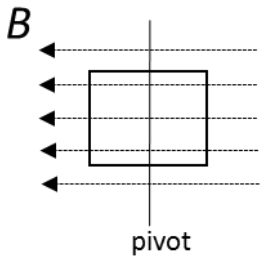
C



D



28 A 20-turns square coil of side 8.0 mm is pivoted at its centre and placed in a magnetic field of flux density, B = 0.010 T such that 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

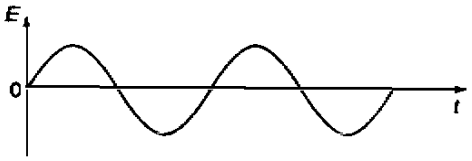
D 3.2×10^{-5} N m

29 A flat circular coil of 120 turns, each of area 0.070 m^2, is placed with its plane perpendicular to a uniform magnetic field. The flux density of the field is changed steadily from 80 mT to 20 mT over a period of 4.0 s.

What is the average e.m.f. induced in the coil during this time?

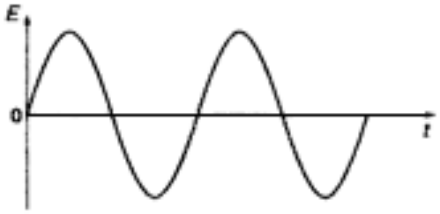
A 0 **B** 0.13 V **C** 0.17 V **D** 0.50 V

30 When a coil is rotated in a magnetic field, the induced e.m.f. *E* varies as shown.

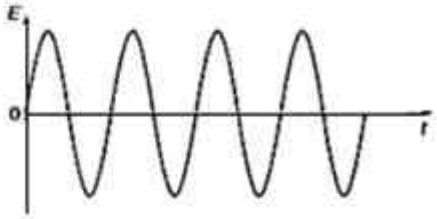


Which of the following graphs, drawn to the same scale, would be obtained if the speed of rotation of the coil were doubled?

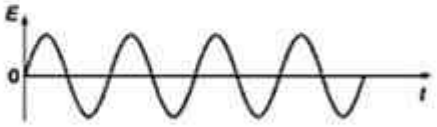
A



B



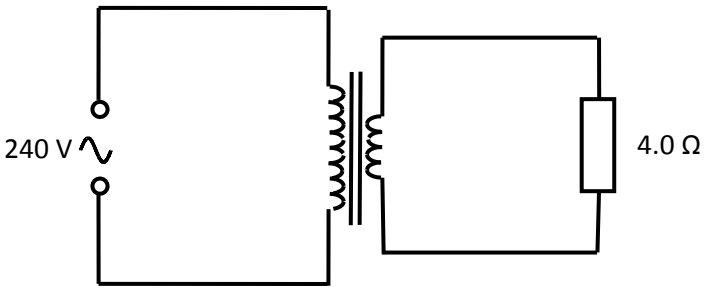
C



D



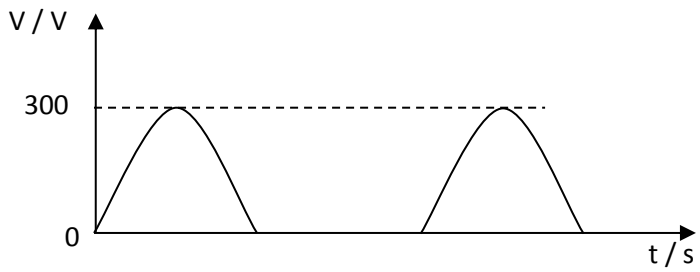
31 An ideal transformer is used to step down a 240 V a.c. voltage supply to a 4.0 Ω resistive load. The ratio of the secondary turns to the primary turns is 1:20.



What is the current in the primary coil?

A 0.15 A **B** 3.0 A **C** 6.0 A **D** 60 A

32 Half-wave rectification of an alternating sinusoidal voltage of amplitude 300 V gives the waveform shown in the figure below.



The r.m.s. value of the rectified voltage is

A 50.0 V **B** 150 V **C** 212 V **D** 300 V

33 What is the de Broglie wavelength of a proton moving with a speed of 1.5×10^{7} m s^{-1}?

A 1.3×10^{-15} m
B 2.6×10^{-14} m
C 4.9×10^{-11} m
D 8.0×10^{-6} m

34 When a metal is irradiated with monochromatic radiation, electrons are emitted. Which of the following will increase if the frequency of the radiation is increased?

A The threshold frequency of the metal.

B The rate of emission of electrons.

C The stopping potential of the electrons.

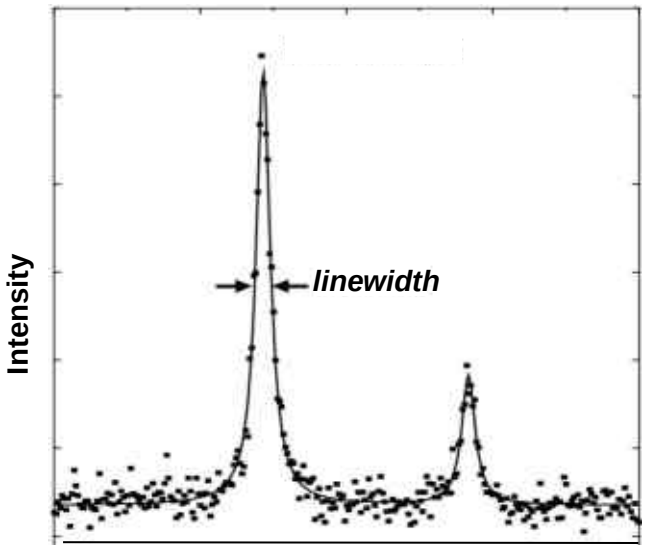
D The maximum speed of the photons.

35 A mercury vapour lamp is rated at 60 W. Of the power supplied, 15% is emitted as blue light of wavelength 4.4×10^{-7} m.

How many quanta of the blue light are emitted per second from this lamp?

A 1.4×10^{19}
B 2.0×10^{19}
C 1.3×10^{20}
D 5.0×10^{20}

36 A researcher obtained an emission spectrum for hydrogen, part of which is shown in the figure below:



The emission lines which represent electronic transitions between discrete energy levels are not perfectly sharp, but instead display finite linewidths as present above.

Which of the following best accounts for this phenomenon?

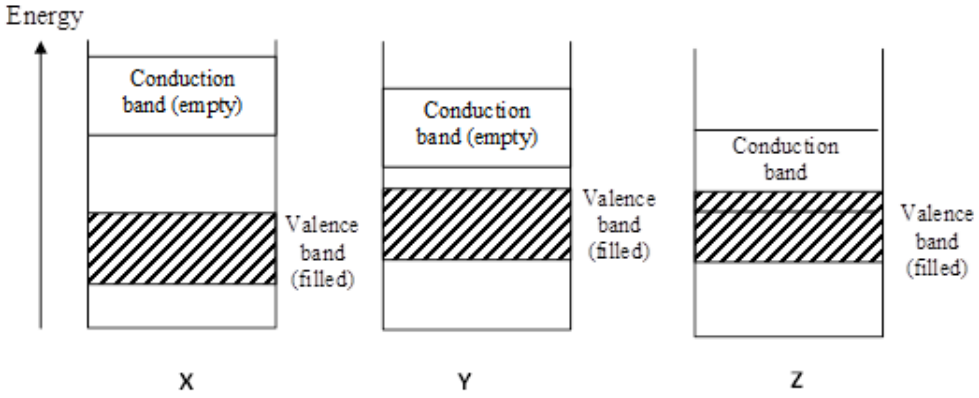
A wave-particle duality of photons

B quantum tunneling of electrons

C position-momentum uncertainty principle

D energy-time uncertainty principle

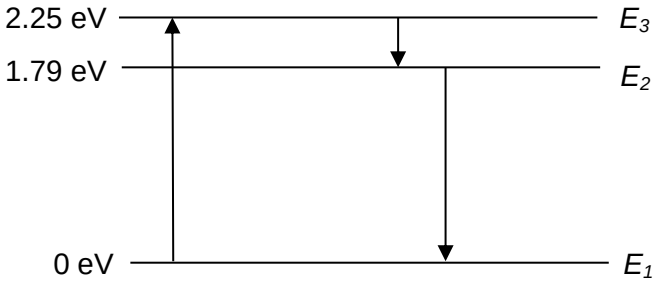
37 The diagram below shows the energy band structure of three materials X, Y and Z.



Which of the following states correctly the types of material that X, Y and Z belong to?

	Conductor	Semi-conductor	Insulator
A	X	Z	Y
B	Y	X	Z
C	X	Y	Z
D	Z	Y	X

38 In a ruby laser, light of wavelength 550 nm from a xenon flash lamp is used to excite the chromium atoms in the ruby from ground state E_1 to state E_3. In subsequent de-excitations, laser light is emitted.



Which of the following correctly shows the metastable state and the wavelength λ of the laser produced?

	Metastable state	**Wavelength λ / nm**
A	E_3	550
B	E_3	2700
C	E_2	690
D	E_2	2700

39 $^{232}_{90}Th$ decays via a series of α, β, and γ decays to the stable isotope $^{208}_{82}Pb$.
Which row describes what can be deduced about the numbers of each decay type?

	number of α decays	number of β decays	number of γ decays
A	6	4	cannot tell
B	6	4	10
C	4	6	cannot tell
D	4	6	10

40 Polonium-210 is a radioactive isotope with a half-life of 138 days. The count rate of a sample of Polonium-210 was found to be 83.2 counts per second. If the background radiation is 8.4 counts per second, what will the count rate be 7 days later?

A 72.2 counts per second

B 80.0 counts per second

C 80.3 counts per second

D 80.6 counts per second

Name : _____ CT group: 15S_____

VICTORIA JUNIOR COLLEGE
2016 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **9646/02**

Higher 2 **14 Sep 2016**

Paper 2 Structured Questions **WEDNESDAY**

2 pm – 3.45 pm

1 Hour 45 minutes

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.

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	
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g	
Total (max. 72)	

This document consists of **20** printed pages.

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}

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, $p = h\rho g$

gravitational potential, $\phi = -\frac{GM}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm\omega\sqrt{(x_o^2 - x^2)}$

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, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$
where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1. In a certain engine, a small amount of ideal gas is introduced into the engine at an initial pressure of 9.0×10^5 Pa and volume of 1.50×10^{-3} m^3, and is made to undergo a 3-stage process:
   (1) Process A $\rightarrow$ B: adiabatic contraction until a volume of 0.50×10^{-3} m^3 and pressure of 42.0×10^5 Pa;
   (2) Process B $\rightarrow$ C: isothermal expansion until a pressure of 14.0×10^5 Pa is reached;
   (3) Process C $\rightarrow$ A: isovolumetric reduction in pressure.

(a) Sketch a pressure – volume graph to show the cycle that the gas undergoes. [1]

(b) The work done in process A $\rightarrow$ B is 1900 J. Calculate the change in internal energy of the gas. State whether it is an increase or decrease. [2]

Change in Internal Energy =..... J

(c) For the process C $\rightarrow$ A, calculate the change in internal energy of the gas. State whether it is an increase or decrease; [2]

Change in Internal Energy =..... J

2. A small ball of mass m is fixed to one end of a light rigid rod. The ball is made to move at constant speed around the circumference of a vertical circle with centre at O, as shown in Fig. 2.1.

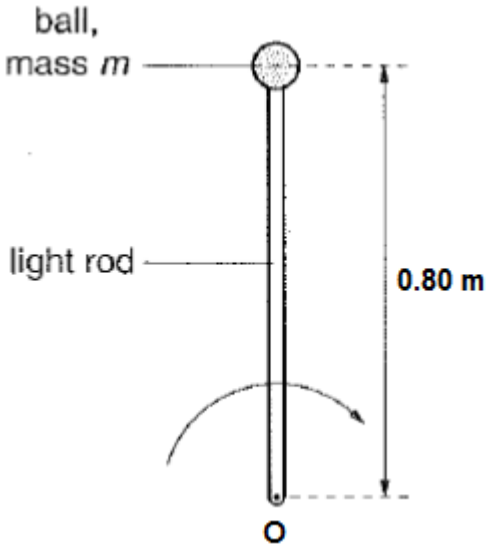


Fig.2.1

When the rod is vertical with the ball above O, the tension T in the rod is given by

$$T = 3\,mg$$

where g is the acceleration of free fall.

(a) (i) Explain why the centripetal force on the ball is greater than $3\,mg$. [1]

(ii) State, in terms of mg, the magnitude of the centripetal force. [1]

(iii) Determine the magnitude of the tension, in terms of *mg,* in the rod when the rod is vertical, with the ball below point O. [1]

(b) The distance from the centre of the ball to point O is 0.80m. Use your answer in (a)(ii) to determine. for the ball,

(i) the angular speed, [3]

Angular Speed =..... rad s^{-1}

(ii) the linear speed. [2]

Speed =..... m s^{-1}

3 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.

The figure below shows a graph of acceleration, a, against displacement (from equilibrium), x, for the vertical motion of the car.

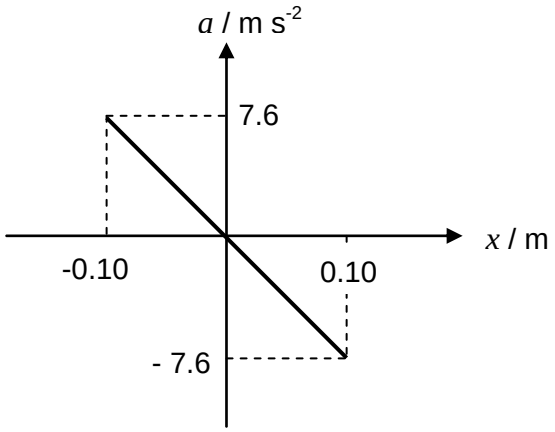


Figure 3.2

(a) Calculate the period of the car's vertical oscillation. [2]

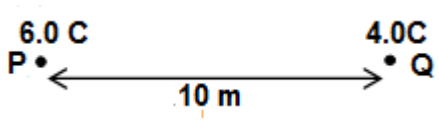
Period =..... s

(b) Calculate the shortest time taken t for the car to oscillate from its *lowest point* to a point 0.025 m *below* its equilibrium position. [3]

t =..... s

(c) If the car travels at a certain speed over this rough road, the vertical oscillations can be very large. Explain why this is so. [2]

4. Two electrical charges, P and Q, of 6.0 C and 4.0 C respectively, are placed 10 m apart.



(a) Calculate the distance between P and a point X, where the resultant electric field strength due to P and Q is zero. [3]

Distance =..... m

(b) Calculate the resultant electric potential at X due to P and Q. [2]

Electric Potential =..... V

(c) The answer in (b) is non-zero although the forces experienced by a charge moving from infinity to point X at the start and end of the process are zero. Use the definition of potential difference to explain why this is so. [2]

5. A circular coil is placed with its axis vertical and a bar magnet, with its axis aligned with the axis of the coil, is held above the coil and then dropped as shown in Fig. 5.1

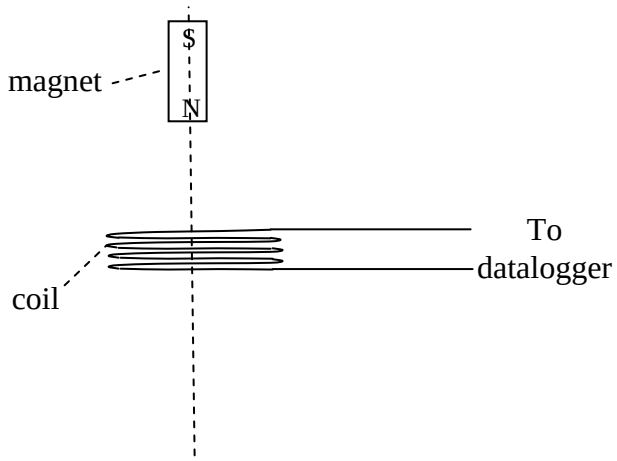


Fig.5.1

The graph in Fig.5.2 shows the variation of the e.m.f. induced in a coil when a bar magnet fell through it.

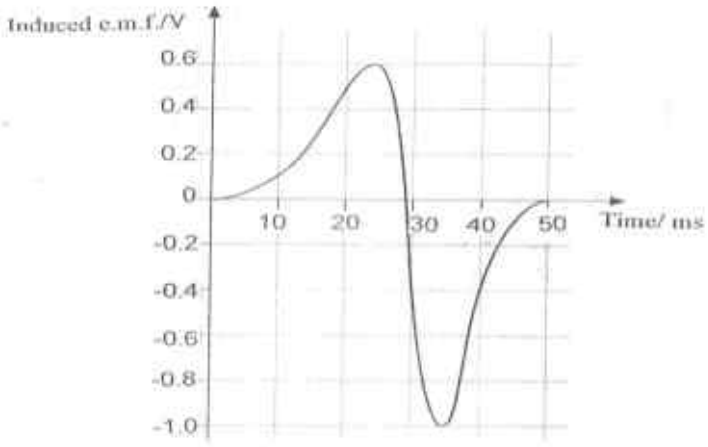


Fig. 5.2

(a) Explain, using the laws of electromagnetic induction, why

(i) Induced e.m.f.s in opposite directions are observed and [2]

(ii) the magnitude of the negative induced e.m.f is larger than the positive induced e.m.f [2]

(b) With reference to Fig. 5.2,

(i) State the quantity which the area under the graph represesnts. [1]

(ii) State the time *t* when the rate of change of flux linkage is maximum.[1]

Time, *t* =..... s

(iii) State the maximum rate of change of flux linkage. [1]

Rate of change of flux linkage =..... Wb s^{-1}

6(a) A laser used to weld metal in a shipyard emits pulses of light of wavelength 650 nm. The duration of each pulse is 50 ms. If the average power output of the pulse is 8.0 kW, calculate

(i) the energy that is deposited on the metal per pulse, and [1]

Energy per pulse =..... J

(ii) the number of photons each pulse contains. [2]

No. of photons =.....

(b) Discuss with the aid of diagrams and using the idea of a depletion region, how a p-n junction can act as a rectifier. [4]

7(a) In the early 20th century, Marie Curie drew an illustration similar to Fig. 7 which indicated how the three radiations travelled in air in a uniform magnetic field. (Fig. 7 is not drawn to scale.)

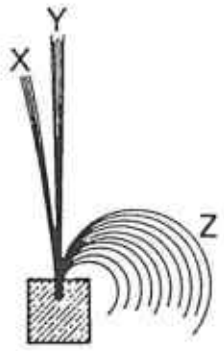


Fig. 7

Identify the radiations X, Y, Z. [1]

X : _____ Y : _____ Z : _____

(b) The uniform magnetic field has a flux density of 0.32 T.

(i) Estimate the speed of a particle of radiation X. [1]

Speed =..... m s^{-1}

(ii) Hence calculate the radius of curvature of the path of a particle of radiation X. [3]

(c) Give two reasons why it is difficult, if not impossible, to take a photograph which is like Fig. 7. [2]

8. **Seismic waves and seismic reflection survey**

Earthquakes are caused by sudden rock movements underground. The vibrations produce seismic waves through the Earth. These waves can be detected many thousands of kilometres away by a seismograph. The incoming vibrations are measured by a sensitive vibration detector and recorded as a function of time. The graph produced is called a seismogram. Fig. 8.1 shows a schematic diagram of the detector and a typical seismogram.

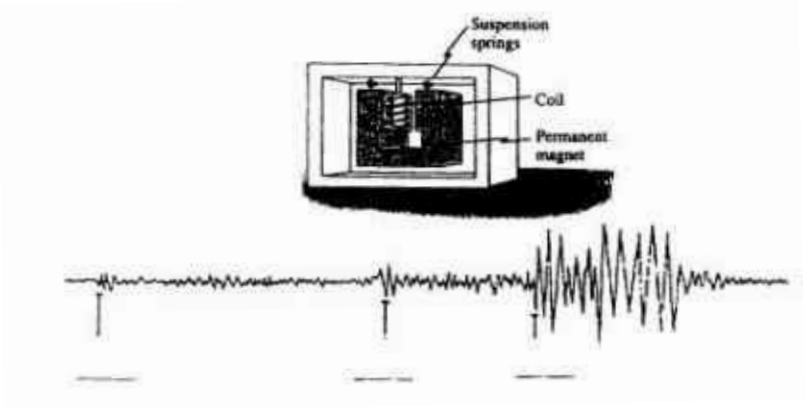


Fig. 8.1

Recordings like this show that there are three main types of seismic waves.

P-waves are longitudinal waves or compression waves. They are the fastest and arrive first. They travel through solids and liquids deep inside the Earth. Their speed is highest through solids.

S-waves are transverse waves or shear waves. They arrive after the P-waves because they are slower. They can pass through solids deep in the Earth., but not through liquids such as molten rock. They are more likely to cause damage than the P-waves.

L-waves or surface waves are the slowest and arrive last. They travel round the Earth's surface and produce a rolling motion, rather like waves at sea. In the earthquake zone itself, they are the most destructive.

(a) On Fig. 8.1, label using the letters P, S and L, the section of the seismogram that correspond to the arrival of the P-, S- and L- waves respectively. Explain briefly how you arrive at your answer. [3]

(b) Waves travel faster in denser rock. A study of the variation in their speed as they travel through the Earth will give clues about the Earth's inner structure and density. Fig. 8.2 shows the variation in speed of P-waves inside the Earth.

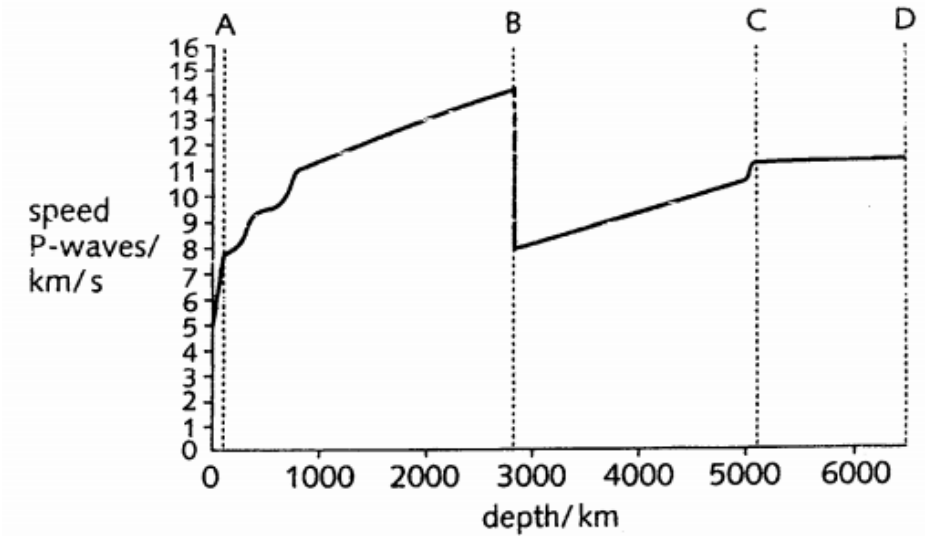


Fig. 8.2

With reference to Fig. 8.2, describe the structure of the Earth around the depth represented by B in Fig. 8.2. [2]

(c) When conducting geological surveys for the purpose of prospecting for oil or minerals, one frequently used method is *seismic reflection surveying*.

In a region where there is a change in rock type at a certain depth, an explosion is set off. This is indicated by the point S_0 in Fig. 8.3. Eight detectors D_1, D_2, … D_8 are arranged as shown in Fig. 8.3, and these detect vibrations from the explosion at S_0. The path taken by the wave travelling from S_0 to D_1 after reflection from the boundary between two rock layers is labelled as 'Route 1'.

The traces received from the eight detectors are printed alongside one another in Fig. 8.4.

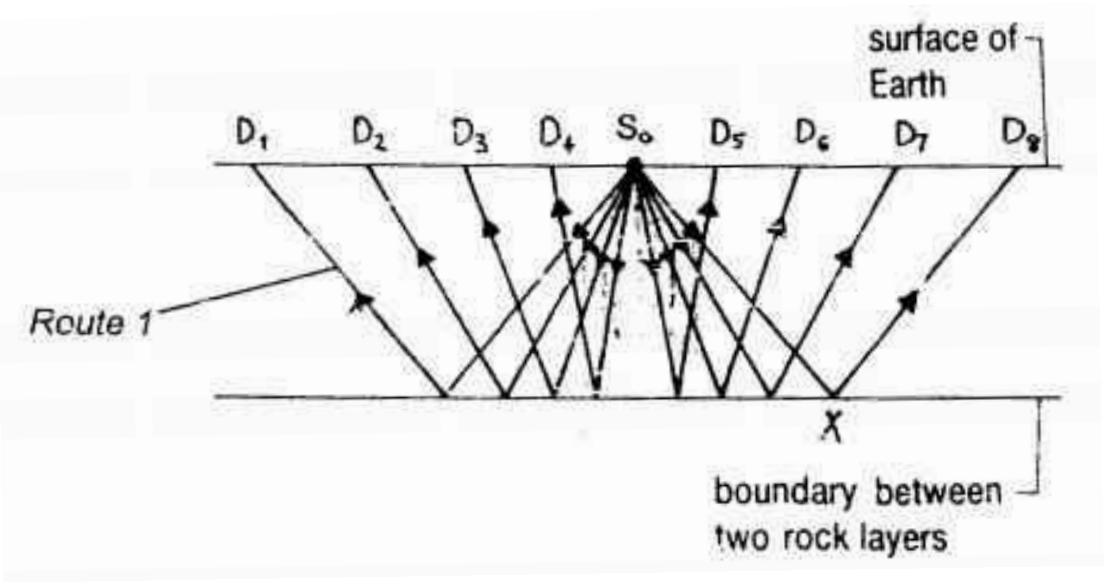


Fig 8.3

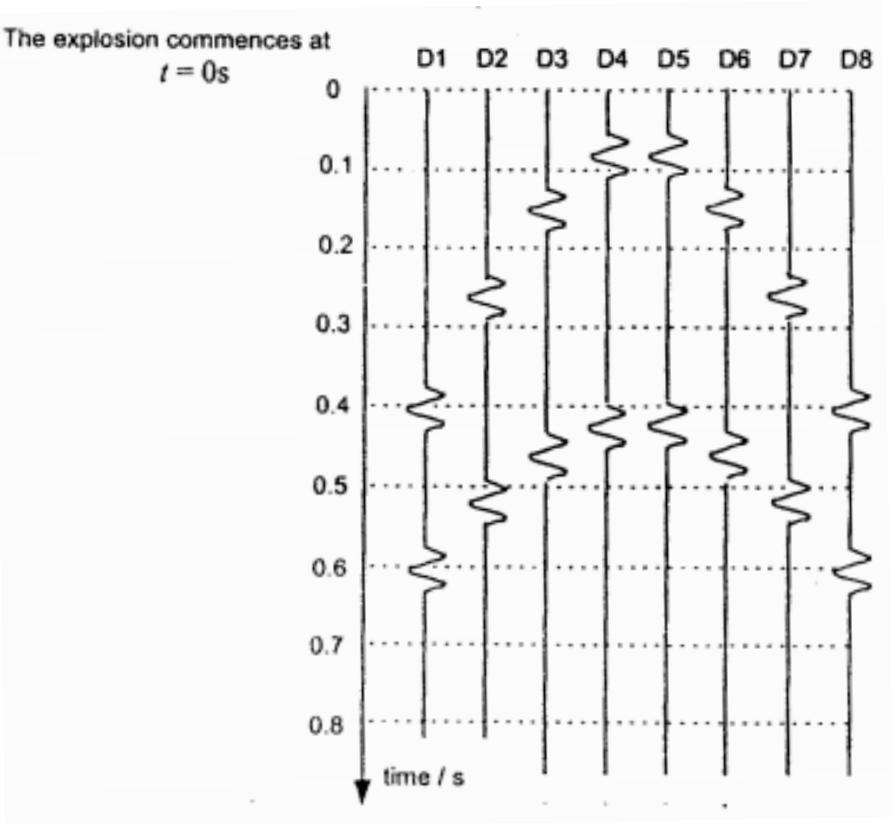


Fig. 8.4

The rocks through which the waves are travelling are known to have a density of 2700 kg m^{-3} and the speed of P-waves in these rocks is 3.1 km s^{-1}.

(i) Draw, on Fig. 8.3, another simple route that P-waves can take to get from S_0 to detector D_1 apart from Route 1 shown. Label it as 'Route 2'. [1]

(ii) Label, on the trace recorded by detector D_1 on Fig. 8.4, the two routes corresponding to the two pulses received as 'Route 1' and "Route 2' respectively. [2]

(iii) Determine the distances S_0D_8 and S_0XD_8. [2]

Distance S_0D_8 =.....km

Distance S_0XD_8 =.....km

(iv) Hence determine the depth of the boundary between the two layer. [2]

Depth of boundary =.....km

9. A contractor uses panels to divide a large room into smaller ones. He intends to use a new sound-absorbing material to make the panels. He engages a sound engineer to study the effectiveness of the material in absorbing sound.

The sound engineer defines the transmission coefficient of a material, T, as $\frac{I_t}{I_0}$, where

I_t = intensity of sound transmitted through the material,
I_0 = intensity of sound incident on the material.

He believes that T depends on the thickness of the panel, d, according to the equation

$$T = ad^n, \qquad \text{where } a \text{ and } n \text{ are constants.}$$

Design an experiment to determine the values of a and n. Equipment available to you include large panels made of the same sound-absorbing material, a loudspeaker, a sound intensity meter and standard laboratory equipment.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the method by which the values of a and n are to be determined,
(b) additional equipment to be used,
(c) the procedure to be followed,
(d) control of variables,
(e) any precautions which you would take regarding accuracy and safety. [12]

Diagram

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End of Paper

Name : _____ CT group : 15S_____

VICTORIA JUNIOR COLLEGE
2016 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **9646/03**

Higher 2 **19 Sep 2016**

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.

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	
Section A	
1	
2	
3	
4	
Section B	
5	
6	
7	
sf	
Units	
g	
Total (Max 80)	

This paper contains a total of 18 pages

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}

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, $p = h\rho g$

gravitational potential, $\phi = -\dfrac{GM}{r}$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$v = \pm\omega\sqrt{(x_o^2 - x^2)}$

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, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$
where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer all questions in this section

1. A traffic policeman hiding behind a signboard detects a car speeding past him with a constant speed of 150 km h^{-1}. He starts his motorcycle 3.0 seconds later and gives chase, accelerating uniformly at 12 m s^{-2}. He overtakes the car at time t_1. The time when the car speeds past the policeman is taken to be t = 0.0 s.

(a) On the same axes, sketch a speed – time graph for the car and motorcycle. Indicate on the time axis, the moment when the motorcycle overtakes the car as t_1. [3]

(b) Hence or otherwise, calculate t_1. [3]

(c) (i) Calculate the time when the speeds of the motorcycle and the car are the same. [1]

(ii) Hence calculate the largest separation between the car and the motorcycle. [3]

2. The simplified diagram in Fig 2 represents the trunk of a person bent forward, with the spine at an angle of 70.0^o to the vertical. The extensor muscle, which joins the spine to the pelvis, makes an angle of 8.0^o to the spinal column. The weight *W* of the person's trunk and head, which is 400 N, is shown to act at the point along the spine where the extensor muscle is attached.

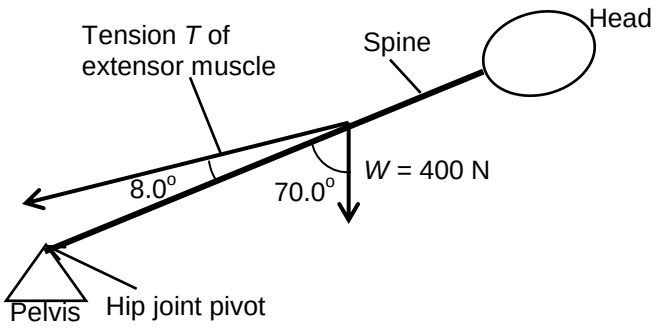


Fig 2

(a) Draw and label an arrow R on Fig 2 to show the direction of the reaction force acting on the spinal column at the hip joint pivot. [1]

(b) Explain why there would be no net moments acting on the body. [1]

(c) (i) Explain why the tension *T* of the extension muscle, the weight *W* and the reaction force *R* must form a closed triangle. [1]

(ii) Hence, or otherwise, calculate reaction force *R* at the hip joint and the tension *T* in the extensor muscle. [4]

(d) Explain why it is advisable to lift heavy objects with the spine almost vertical. [2]

3(a) Define magnetic flux density [1]

(b) A rectangular coil of *N* number of turns is lying with its plane at an angle to a horizontal uniform magnetic field *B* as shown in Fig 3.1. LM=KN=*y* and KL=MN=*x*. The coil carries a current of *I*. Fig 3.2 shows the view from the side KL.

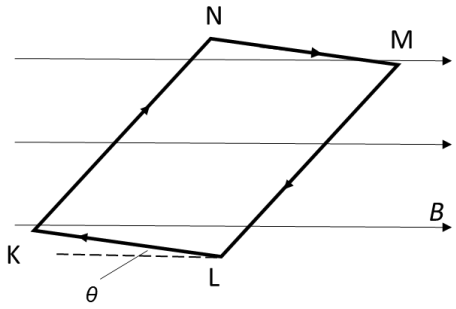


Fig 3.1

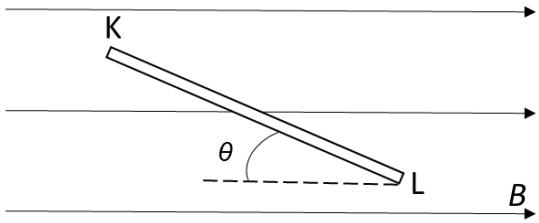


Fig 3.2

(i) Draw all the magnetic forces acting on the coil in Fig 3.1. [2]

(ii) Derive an expression for the torque τ acting on the coil in terms of *x*, *y*, *N*, *I*, *B* and θ. [2]

(c) A moving coil galvanometer, as shown in Fig 3.3 is constructed such that the plane of the coil (N turns, area A) remains parallel to the magnetic field *B* during rotation by using a radial field.

Fig 3.4 shows the schematic diagram of the galvanometer. A soft-iron core is fixed centrally between the semi-polar pole pieces of a permanent magnet. The coil is also held centrally between the pole pieces and it has a pointer attached. The coil moves in the space between the soft iron core and the magnet. A restraining torque provided by the spiral springs placed above and below the coil is used to measure the current *I* flowing through the coil.

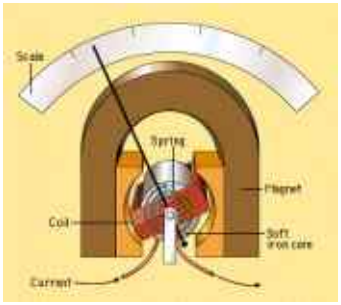


Fig 3.3

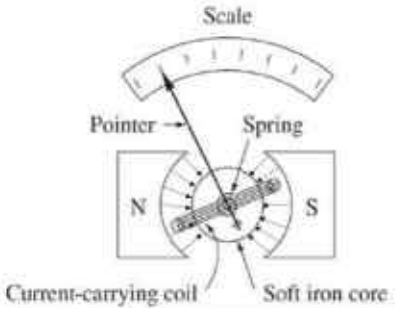


Fig 3.4

Torque provided by current in coil in radial field $\tau_{coil} = NBIA$, where *A* = *xy*,

Restraining torque supplied by spiral springs $\tau_{spring} = k\phi$,

where *k* is the spring constant and ϕ is the angle of deflection of the pointer from the zero point.

(i) Explain why when the pointer comes to rest, the deflection of the pointer ϕ is proportional to the current in the coil. [2]

(ii) Using the results of (b)(ii) and (c)(i), or otherwise, suggest why a radial field is used instead of a uniform field, in a galvanometer. [2]

(iii) Suggest how the sensitivity of the galvanometer can be increased. [1]

4. A fully charged car battery has an e.m.f. of 12 V and an internal resistance of $2.6 \times 10^{-2}\ \Omega$. This battery has the capacity to deliver a constant current of 2.1 A for a period of 5.0 hours.

(a) Calculate the total number of electrons passing through the battery in a time of 5.0 hours while delivering a constant current of 2.1 A. [2]

(b) The fully charged car battery is connected to a starter motor, four sidelights and two headlights as shown in Fig. 4.1.

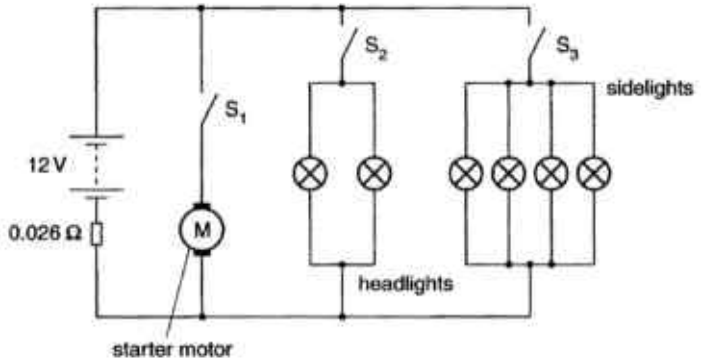


Fig. 4.1

At 12 V, the power rating of each headlight is 48 W. When operating at 12 V, the material of the filament has resistivity $7.9 \times 10^{-7}\ \Omega$ m and diameter 1.8×10^{-4} m.

(i) Calculate the resistance of a single headlight. [2]

(ii) Calculate the length of the filament of the headlight. Comment on your answer. [3]

(iii) The resistance of each sidelight is 24 Ω. Calculate the current in the battery when switches S_2 and S_3 are closed and switch S_1 is open. [2]

(iv) The sidelights and headlights are switched on. With S_1 closed, the current in the starter motor is 120 A. Explain why all the lights become less bright when S_1 is closed. [2]

Section B

Answer **two** questions from this section

5(a) Explain what is meant by the [2]

(i) phase difference between two waves,

(ii) coherence of two waves.

(b) A sound system has two speakers S_1 and S_2 connected to the same source and placed at a distance of 1.2 m apart as shown in Fig 5.1. The speakers emit sound of frequency 2.8 kHz at a speed of 336 m s^{-1}.

A detector D is moved along the line XAY where A is equidistant from S_1 and S_2. The speaker S_1 emits a signal that arrives at point A with intensity *I*, and the speaker S_2 emits a signal that arrives at point A with intensity 3*I*.



Fig 5.1

(i) Determine the intensity of the sound detected at A in terms of *I*. [3]

(ii) B is at a distance 3.72 m from S_1 and 4.02 m from S_2. Explain whether the detector receives a maximum or a minimum signal at B. [2]

(iii) When the detector D is fixed at point B, a series of maximum and minimum values can be obtained by gradually increasing the frequency emitted by the speakers. Explain this phenomenon. [3]

(c) A diffraction grating with 250 lines per mm is placed in front of a red laser pointer. A screen placed 200 cm beyond the grating has red images measured at certain positions on a scale on the screen, as shown in Fig 5.2.

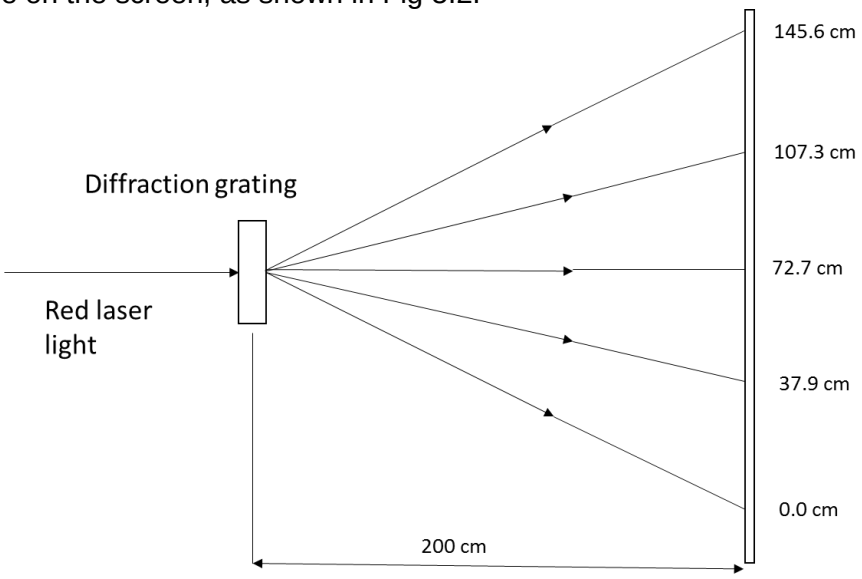


Fig 5.2

(i) Deduce the wavelength emitted by the laser. [3]

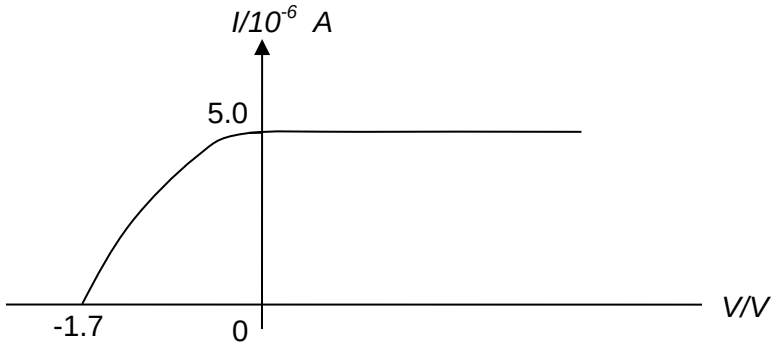
(ii) In reality, a red laser actually has a small range of frequencies of red light that it emits. Suggest what would actually be observed on the screen. [1]

(iii) Explain the changes, if any, to the pattern formed on the screen if a blue laser light is used instead. [2]

(d) A stationary wave is set up in a string in certain mode of vibration for which a point a quarter of its length from one end is a point of maximum vibration and the frequency is the lowest possible. The note has a frequency of 100 Hz.

Calculate the frequency emitted when it vibrates in the next mode such that this point is again a point of maximum vibration. [4]

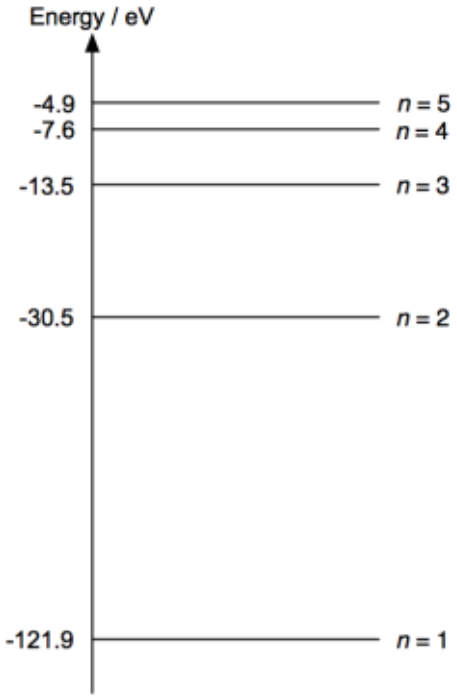
6(a) In a typical set-up for the photoelectric experiment, a metal surface is illuminated with radiation of wavelength 420 nm, causing the emission of photoelectrons, which are collected at an adjacent electrode. The graph below shows, for a given intensity, how the photoelectric current, *I* varies with the potential difference, *V* between the electrodes.



(i) Determine the threshold wavelength of this metal. [3]

(ii) Explain the significance of this threshold wavelength in relation to the nature of light. [2]

(b) The figure below shows a simplified representation of the 5 lowest energy levels of doubly ionised lithium (Li^{2+}) that has only one electron. Take the energy level of $n = \infty$ to be 0.0 eV.



(i) Explain how emission spectral lines provide the evidence for the existence of discrete energy levels in an atom. [2]

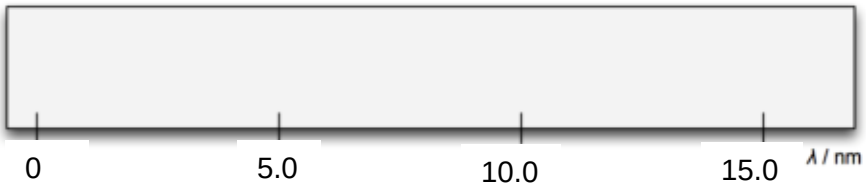
(ii) Explain why the ionised lithium vapour in a discharge lamp must be at low pressure in order to produce an emission spectrum. [1]

(c) Considering transitions between only these levels,

(i) calculate the wavelengths of the spectral transitions that produce the shortest and longest wavelengths. [3]

(ii) state the number of emission spectral lines that can be produced by transitions among these levels. [1]

(d) Sketch the emission spectrum of the lithium vapour corresponding to *only* those transitions that involve the $n = 1$ energy level. Use vertical lines to denote the relative positions of the spectral lines. [3]



(e) (i) 1. Explain what is meant by the term *ionisation energy.* [1]

2. State the value of the ionisation energy of the lithium ion. [1]

(ii) The work function of lithium metal is less than 3.0 eV. Explain, using band theory, why the ionisation energies of an atom are always higher than the work function of the metal of the same element. [3]

7(a) Explain what is meant by

(i) the *activity* of a radioactive source, [1]

(ii) the *decay constant* of a nuclide, [1]

(iii) the *half-life* of a nuclide. [1]

(b) Bismuth-214 ($^{214}_{83}$Bi) has an unusual decay pattern. Sometimes it decays by α emission into thallium (Tl) and sometimes by β emission into polonium (Po).

(i) Write nuclear equations for these two decays of $^{214}_{83}$Bi. [2]

(ii) The rest masses of the three particles involved in the α decay of $^{214}_{83}$Bi are given below.

Particle	Rest mass / *u*
Bi (bismuth)	213.9987
Tl (thallium)	209.9901
α	4.0015

Calculate the energy released in this decay. [3]

(iii) The two decay patterns of the $^{214}_{83}$Bi each give rise to γ ray photons. Suggest why each of these photons have different energies. [2]

(c) (i) Without numerical values, sketch a labelled graph below to show how, starting with only $^{214}_{83}$Bi nuclei, the activity of the $^{214}_{83}$Bi changes with time. [1]

(ii) The thallium (Tl) produced is also radioactive and has a shorter half-life than $^{214}_{83}$Bi. On the same axes in (c)(i), sketch another graph to suggest how the activity of the Tl changes with time. [1]

(d) A sample of $^{214}_{83}$Bi has mass 2.0 μg at time t = 0.

(i) Show that the sample contains approximately 5.6×10^{15} atoms. [1]

(ii) The activity at t = 0 is 3.3×10^{12} Bq. Calculate the decay constant. [2]

(iii) Calculate the half-life. [1]

(iv) Calculate the time taken for the activity to fall to 3.3×10^{6} Bq. [2]

(e) The $^{214}_{83}$Bi sample is stored in a (non-radioactive) lead container. Suggest why, although the lead container provides adequate shielding for the α and β emissions, some X-ray radiation may be detected outside the lead container. [2]

End of paper

2016 VJC Prelim H2 Paper 1 ***Suggested Solutions***

1	**A**	*9*	**C**	*17*	**A**	*25*	**C**	*33*	**B**
2	**B**	*10*	**D**	*18*	**D**	*26*	**C**	*34*	**C**
3	**A**	*11*	**A**	*19*	**D**	*27*	**A**	*35*	**B**
4	**B**	*12*	**C**	*20*	**C**	*28*	**C**	*36*	**D**
5	**D**	*13*	**B**	*21*	**C**	*29*	**B**	*37*	**D**
6	**B**	*14*	**B**	*22*	**C**	*30*	**B**	*38*	**C**
7	**C**	*15*	**C**	*23*	**C**	*31*	**A**	*39*	**A**
8	**C**	*16*	**A**	*24*	**C**	*32*	**B**	*40*	**D**

1 **Ans: A**

Energy produced = Pt

$= 3.0 \times 10^{9} \times 2.0 \times 10^{-12}$

$= 6.0 \times 10^{-3}$ J

$= 6.0 \times 10^{-15}$ TJ

2 **Ans: B**

Uncertainty of period = $\frac{0.5 + 0.5}{20}$

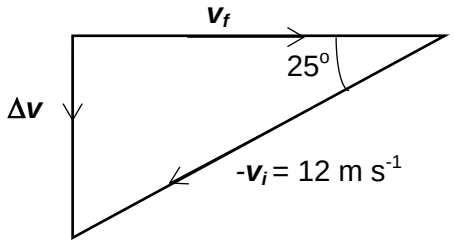
= 0.05 s

3 **Ans: A**

- The ball starts with zero speed. So when $s = 0$, $v = 0$.
- The ball can move either up or down. So v should change sign.
- But the ball is always below the point P. So s should always have the same sign.

4 **Ans: B**

Remember: $\Delta \boldsymbol{v} = \boldsymbol{v_f} - \boldsymbol{v_i}$



The horizontal component of $\boldsymbol{v_i} = \boldsymbol{v_f}$ since there's no horizontal acceleration, so $\Delta \boldsymbol{v}$ is vertical.

$\Delta \boldsymbol{v} = 12 \sin 25^{o}$

$= 5.1$ m s^{-1}

5 **Ans: D**

Taking moments about pivot:

W_{rubber} x (1.90 L) = W_{steel} x (0.10 L)

1.0Lx A x ρ_{rubber} x 1.90Lg = 3.00L x A x ρ_{steel} x 0.10L

$\Rightarrow \quad \frac{\rho_{steel}}{\rho_{rubber}} = \frac{1.0LA \times 1.90L}{3.00LA \times 0.10L}$

$= 6.33$

6 Ans: B

Torque by a couple = F x perpendicular distance between them
= F x L sinθ

7 Ans: C

Statement C is **<u>false</u>** because the collision forces are internal, not external, forces, and so the total momentum of the system should be conserved throughout the whole duration of the collision.

8 Ans: C

Area under F-t graph = change in momentum
½ x (30 + 15)x 1500 – ½ x15 x 1500 = m(v – 10)
v = 32.5 m s^{-1}

9 Ans: C

Since object is at constant speed up the inclined plane:
Total w.d by 50 N force = Gain in GPE + w.d against friction
1500 = 50 x 12 + w.d against friction
∴ w.d against friction = 1500 – 600 = 900 J

10 Ans: D

When boat is travelling at constant speed v, the driving force is equal to the drag force. Then the power P is given by:

$P = Fv$
$= Dv$
$= (kv^2)v$

i.e. $P = kv^3$

When both engines are working:

$2 \times 30\ kW = k(10)^3$ - - - - (1)

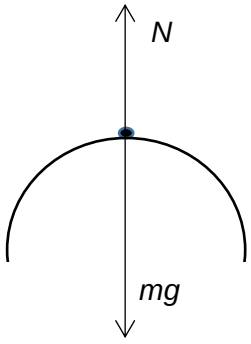
When only one engine is working:

$30\ kW = kv^3$ - - - - (2)

(2)/(1): and solve for v:

v = 7.9 m s^{-1}

11 Ans: A



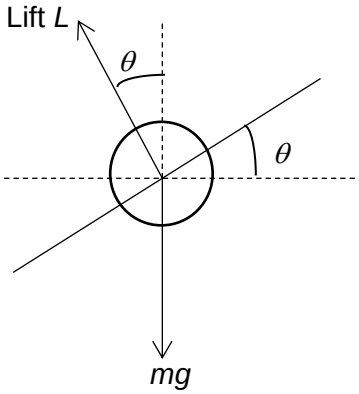
$$mg - N = \frac{mv^2}{r}$$

$$N = mg - \frac{mv^2}{r}$$

$$= (1400 \times 9.81) - \frac{1400 \times \left(\frac{30 \times 10^3}{3600}\right)^2}{9.0}$$

$$= 2900 \text{ N}$$

12 Ans: C



Horizontally, $L\sin\theta = \frac{mv^2}{r}$ (1)

Vertically, $L\cos\theta = mg$ (2)

(1)/(2) $\tan\theta = \frac{v^2}{rg}$

$$\theta = \tan^{-1}\frac{v^2}{rg}$$

$$= \tan^{-1}\left(\frac{\left(\frac{520 \times 10^3}{3600}\right)^2}{360 \times 9.81}\right)$$

$$= 80^o$$

13 Ans: B

For molecule to escape, it must be given enough KE to overcome the GPE.

$\frac{1}{2} m v^2 = 0 - \left(\frac{-GMm}{r}\right)$

$$v = \sqrt{\frac{2GM}{r}}$$

$$v \propto \sqrt{\frac{1}{r}}$$

$$\frac{v_{1.2R_E}}{v_{R_E}} = \sqrt{\frac{R_E}{1.2\,R_E}}$$

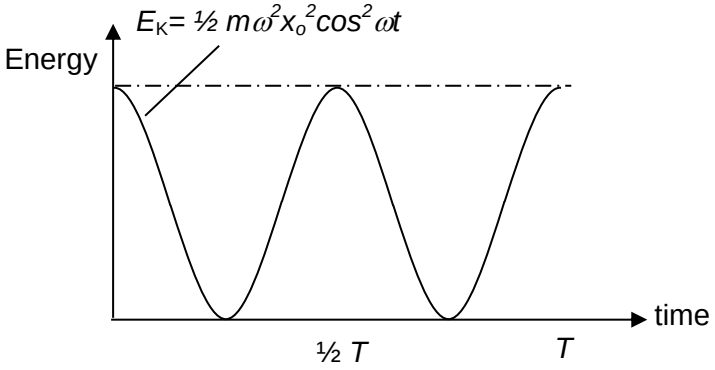
$v_{1.2R_E} = 1.0 \times 10^4 \text{ m s}^{-1}$

14 Ans: B

$$F = -\frac{dU}{dr}$$

The gravitational force is equal to the negative of the gravitational potential energy gradient.

15 Ans: C



From the graph above, the period of the KE graph is T/2.
Therefore its frequency,

$$\mathrm{f}' = \left(\frac{T}{2}\right)^{-1} = \frac{2}{T} = 2f$$

16 Ans: A

For the object to remain in contact with the platform throughout the motion, its acceleration must not be greater than 9.81 m s^{-1}.

$$a_{\max} = \omega^2 x_0$$

$$x_0 = \frac{a_{\max}}{\omega^2} = \frac{a_{\max}}{(2\pi f)^2} = \frac{9.81}{(2\pi(1.5))^2} = 0.11\,\mathrm{m}$$

17 Ans: A

Let the required time be *t*.
By Conservation of Energy,

$$Pt = mc\Delta\theta + C\Delta\theta$$

$$(2.5\times10^3)t = (5.0)(4200)(45-30) + (5000)(45-30)$$

$$t = \frac{315000 + 75000}{2.5\times10^3}$$

$$= 156\,s$$

18 Ans: D

Mean translational kinetic energy of the gas is proportional to the temperature.
Since the gases are at the same temperature, they have the same mean translational kinetic energy.

19 Ans: D

After passing through a polarizer, unpolarised light's intensity is halved (therefore we eliminate options A/B). Amplitude becomes $A/\sqrt{2}$

Since the polarization angle is 75°, using Malus' Law:

$A' = A/\sqrt{2}\cos 75^\circ = A/\sqrt{2}\sin 15^\circ$

20 Ans: C

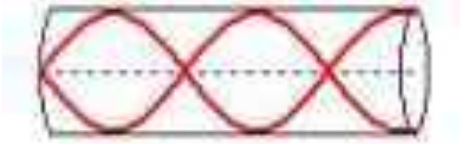
$$I = k\frac{A^2}{r^2}$$

$$\frac{I'}{I} = \frac{A'^2}{A^2}\frac{r^2}{r'^2}$$

$$I' = 5\frac{(2A)^2}{A^2}\frac{3^2}{4^2} = 11.25 \approx 11\,\text{W}\,m^{-2}$$

21 Ans: C

When a loud sound is heard for the 3rd time:



$$\text{l} = \frac{5}{4}\lambda$$

$$15 = 1.25\lambda$$

$$\lambda = 12\,\text{cm}$$

22 Ans: C

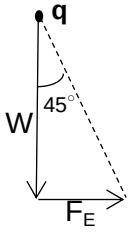
$$\text{path difference}, \Delta x = \sqrt{1.6^2 + 1.2^2} - 1.6 = 0.4\,\text{m}$$

$$\lambda = \frac{v}{f} = \frac{320}{400} = 0.8\,\text{m}$$

$$\therefore \Delta\text{x} = 0.5\lambda$$

The 2 waves arrive out of phase at all times, resulting in destructive interference.

23 Ans: C



$$\tan 45° = \frac{F_E}{W} = \frac{q\left(\frac{V}{d}\right)}{W}$$

$$q\left(\frac{V}{d}\right) = W$$

$$q = \frac{Wd}{V}$$

24 Ans: C

$E = -\frac{dV}{dr} = 0$
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.

25 Ans: C

Recall "*P = IV* ", so *V = P/I*
The electrical potential difference between two points in a wire carrying a current may be defined as the ratio of the power supplied to the current between the points.

26 Ans: C

Applying potential divider principle, the potential difference (p.d.) across R_{XY} is
$V_{XY} = \frac{8.30}{8.30+1.42} \times 9.0 = 7.685$ V
P.d. across the balance length = $\frac{0.745}{1.000} \times 7.685 = 5.73$ V
E_2 = p.d. across the balance length = 5.73 V

27 Ans: A
Since the currents in QR and XY are out of phase, the currents in PS and XY are in phase as PSRQ are in a loop. Like currents attract, therefore the attractive force between them is always positive. Also the currents vary from zero to a maximum, so the attractive force also varies from zero to a maximum.

28 Ans: C
$\tau = Fd$
$= 2F_B \frac{L}{2}$
$= NBIL \times L$
$= 20 \times 0.01 \times 5 \times 10^{-3} \times (8 \times 10^{-3})^2$
$= 6.4 \times 10^{-8}$ N m

29 Ans: B

$Induced\ \text{e.m.f.}, E = \left| -\frac{d\Phi}{dt} \right|$
$= \frac{NA(B_f - B_i)}{\Delta t} = \frac{120(0.070)(20-80)x10^{-3}}{4.0} = -0.126V$
$= -0.13V$

30 Ans: B

induced emf, $E = E_o \sin \omega t$

where E_o = peak value = $BAN\omega$

when speed of rotation of the coil were doubled, ω is doubled and E_o is doubled.

the frequency, $f = \dfrac{\omega}{2\pi}$ would also be doubled.

31 Ans: A

For an ideal transformer,

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \Rightarrow V_S = \frac{N_S}{N_P} V_P = \frac{1}{20}(240) = 12\,\text{V}$$

$$I_S = \frac{V_S}{R} = \frac{12}{4} = 3.0\,A$$

$$\frac{I_P}{I_S} = \frac{N_S}{N_P} \Rightarrow I_P = \frac{N_S}{N_P} I_S = \frac{1}{20}(3) = 0.15\,A$$

32 Ans: B

The mean square value of the half-wave rectified voltage is

$$\langle V^2 \rangle = \frac{1}{2}\left(\frac{300^2}{2}\right) = 22500\,\text{V}^2$$

$$V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{22500} = 150\,\text{V}$$

(Note: area under the V^2-t graph for half wave rectification is half that of full sine graph.

33 Ans: B

de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63\times10^{-34}}{(1.67\times10^{-27})(1.5\times10^{7})} = 2.6\times10^{-14}\ \text{m}$$

34 Ans: C

Increasing the frequency of the radiation will increase the maximum kinetic energy of the electrons. Therefore the stopping potential of the electrons will increase.

35 Ans: B

$$P = \frac{E}{t} = \frac{\text{Nhc}}{\text{t}\lambda}$$

$$\frac{N}{t} = \frac{P}{hc/\lambda} = \frac{(0.15)(60)}{(6.63\times10^{-34})(3.0\times10^{8})/4.4\times10^{-7}} = 2.0\ \text{x}10^{19}\ \text{s}^{-1}$$

36 Ans: D

The spread in the frequencies of emitted photons indicates that there is an uncertainty in the measured values for the energies of the electronic transitions. This is in accordance to Heisenberg energy-time uncertainty principle.

37 Ans: D

Refer to lecture notes

The energy gap between the valence and conduction bands is much smaller in semiconductors than in insulators.

38 Ans: C

E_2 is the metastable state because it is not subjected to stimulated emission caused by the 550 nm photons used in optical pumping, and allows the accumulation of excited electrons to achieve population inversion.

Laser is produced via stimulated emission from E_2 to E_1

Hence, the wavelength is $\lambda = \dfrac{hc}{(E_2 - E_1)} = \dfrac{6.63\times10^{-34}\times3.0\times10^{8}}{(1.79-0)\times1.6\times10^{-19}} = 694\text{nm}$

39 Ans: A

$^{232}_{90}\text{Th} \rightarrow 6\left(^{4}_{2}\text{He}\right) + {}^{208}_{78}\text{X}$

$^{208}_{78}\text{X} \rightarrow 4\left(^{0}_{-1}\text{e}\right) + {}^{208}_{82}\text{Pb}$

So, there are 6 alpha decays and 4 beta decays.

In each decay process, γ-ray photons may or may not be emitted. We do not know how many γ-ray photons are emitted in total.

40 Ans: D

Initial count rate due to the sample alone (minus background count):

$C_0 = 83.2 - 8.4 = 74.8\ \text{s}^{-1}$

After 7 days, the count rate is:

$C = C_0 \exp(-\lambda t)$

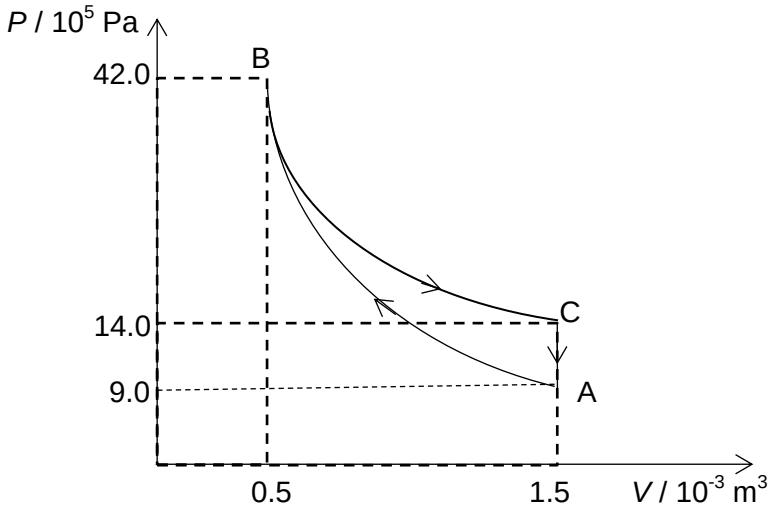
$= (74.8)\exp\left[-\left(\dfrac{0.693}{138\,\text{days}}\right)(7\,\text{days})\right]$

$= 72.2\ \text{s}^{-1}$

Measured count rate (including background count) = 72.2 + 8.4 = 80.6 s^{-1}

VJC 2016 PRELIM H2 P2 (*Suggested Solutions*)

1(a)



(b) $\Delta U_{AB} = Q + W_{on}$
Adiabatic: $Q_i = 0$

ΔU_{AB} = 1900 J (increase)

(c) For a complete cycle,
$\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CA} = 0$
$1900 + 0 + \Delta U_{CA} = 0$ (Isothermal: $\Delta U_{BC} = 0$)
ΔU_{CA} = 1900 J (decrease)

2(a) (i) The centripetal force is the resultant force acting on the mass, and is given by tension + weight of mass. Therefore it is more than the tension = 3 mg.

(ii) Magnitude of the centripetal force = T + *mg* = 4 *mg*

(iii) Below point O,

$$T - mg = \text{centripetal force}$$
$$T = 4\,mg + mg = 5mg$$

(b) (i)

from (a)(ii) centripetal force, $mr\omega^2 = 4mg$

$$\text{angular speed, } \omega = \sqrt{\frac{4g}{r}} = \sqrt{\frac{4x9.81}{0.80}}$$
$$= 7.0\ rad\ s^{-1}$$

(ii) the linear speed, v = r ω
= 0.80(7.0) = 5.6 m s^{-1}

3 **(a)** $a = -\omega^2 x$

$\omega = \sqrt{gradient}$

$= \sqrt{\frac{7.6-0}{0.10-0}}$

$= 8.72 \text{ rads}^{-1}$

$T = 2\pi / \omega$

$= 2\pi / 8.72$

$= 0.72 \text{ s}$

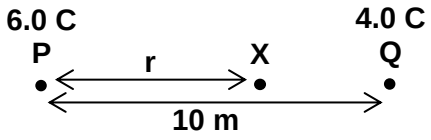
(b) Equation for SHM motion: $x = -x_o \cos \omega t$
(Since starting point is at lowest point of motion)

$-0.025 = -0.10 \cos (8.72\, t)$

$t = 0.15 \text{ s}$

(c) Resonance occurs.
The frequency of passing over the bumps matches the natural frequency of the suspension of the truck.

4(a)



At X: resultant field strength = 0

$$\frac{q_P}{4\pi\varepsilon_0 r^2} = \frac{q_Q}{4\pi\varepsilon_0 (10-r)^2}$$

$$r = \frac{10}{1+\sqrt{\frac{q_Q}{q_P}}}$$

$$= \frac{10}{1+\sqrt{\frac{4.0}{6.0}}}$$

$= 5.51 \text{ m}$

(b) Resultant electric potential $= \frac{q_p}{4\pi\varepsilon_0 r} + \frac{q_Q}{4\pi\varepsilon_0 (10-r)}$

$$= \frac{1}{4\pi \times 8.85 \times 10^{-12}} \left(\frac{6.0}{5.51} + \frac{4.0}{10-5.51} \right)$$

$= 1.78 \times 10^{10} \text{ V}$

(c) Potential difference is defined as the work done per unit positive charge to bring a charge from one point to another.

The unit positive charge being moved from infinity to X will experience repulsion by the charges at P and Q all the time.

So work must be done by an external agent to bring the unit charge from infinity to X.

5(a) (i) When the magnet is approaching the coil, there is an increase in magnetic flux linked with the coil. By Faraday's Law, this rate of change of flux linking the coil induced an emf in the coil.

When the magnet is leaving the coil, there is a decrease in the magnetic flux (which remains in the same direction) linked with the coil. According to Lenz's law, the direction of the induced e.m.f. is such as to oppose the decrease in magnetic flux linked with the coil, thus the e.m.f. induced is in an opposite direction.

(ii) The magnet accelerates (increases in speed) as it falls through the coil and hence the rate of change of magnetic flux linkage is larger. According to Faraday's law, the greater rate of change of magnetic flux linkage is proportional to a greater magnitude of e.m.f. induced.

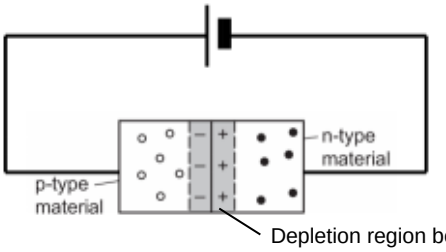
(b) (i) Change in magnetic flux linkage
(ii) t = 35 ms
(iii) Maximum rate of change of flux linkage = 1.0 Wb s^{-1}

6(a) (i) Energy per pulse = Pt
$= 8.0 \times 10^3 \times 50 \times 10^{-3}$
$= 400$ J

(ii) Energy of each photon $= \dfrac{hc}{\lambda}$
$= \dfrac{6.63\times10^{-34}\times3.00\times10^{8}}{650\times10^{-9}}$
$= 3.1 \times 10^{-19}$ J

$\therefore$ Number of photons contained in each pulse = $\dfrac{400}{3.06\times10^{-19}} = 1.3\times10^{21}$

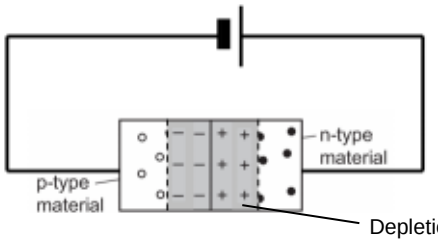
(b) In a p-n junction, electrons diffuse from the n-type to the p-type material and holes diffuse from the p-type to the n-type material, forming immobile charges. This diffusion-recombination process sets up a depletion layer free of mobile charge carriers.



Forward bias

In forward bias, the positive terminal of the cell is connected to the *p*-side. The electric potential of the *p*-side is raised and that of the *n*-side is lowered, thus decreasing the height of the potential barrier ΔV. The reduction in ΔV corresponds to a narrowing of the width of the depletion region and a substantial reduction in the resistance of the junction and the charge carriers can cross the p-n junction easily

(more *n*-side electrons can now surmount this smaller potential barrier and move to the *p*-side. Similarly, more *p*-side holes can move to the *n*-side.) and current can flow across the junction.



Reverse bias

Depletion region becomes wider

In reverse bias, the positive terminal of the cell is connected to the *n*-side. The electric potential of the *n*-side is raised, and that of the *p*-side is lowered. The internal potential barrier ΔV within the junction is increased and the junction acquires a very high resistance. The depletion layer widens and it is now more difficult for the majority charge carriers on either side of the junction interface to cross the junction, so no current can flow across the junction.

Therefore, the p-n junction can act as a rectifier to convert an alternating current to a current that only flow in one direction.

7(a) X : alpha particles Y : gamma radiation Z : beta particles

(b) (i) Estimated speed = 0.1*c* = **3.0×10^7 m s^{-1}**
(Accept 0.05*c* to 0.5*c* = 1.5×10^7 m s^{-1} to 1.5×10^8 m s^{-1})

(ii) Magnetic force = centripetal force

$qvB = \frac{mv^2}{r}$, where *r* is the radius of curvature

$m_\alpha = 4u$ and $q_\alpha = 2e$

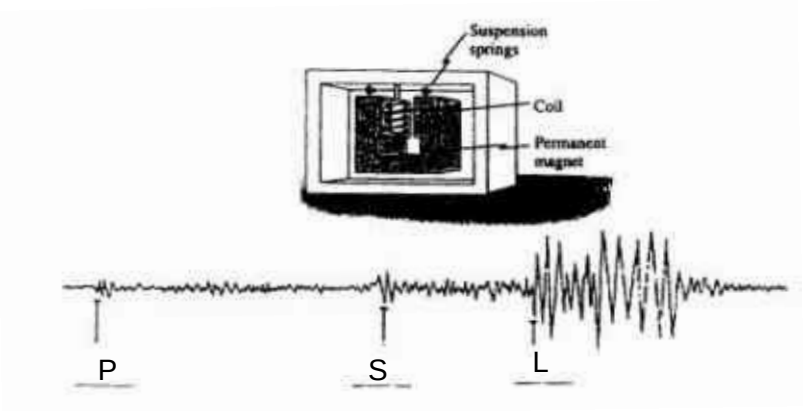
$$r = \frac{m_\alpha v}{q_\alpha B} = \frac{(4u)(0.1c)}{(2e)B} = \frac{(4\times1.66\times10^{-27})(0.1\times3.00\times10^8)}{(2\times1.60\times10^{-19})(0.32)}$$

r = **1.9 m**
(Accept *r* = 0.97 m to 9.7 m)

(c)

- The sizes of the alpha- and beta-particles are extremely tiny, and they are unable to reflect enough light onto a photographic film or into a digital camera, so their images cannot be captured.
- The particles are passing through normal air, so they will not leave any tangible ionization tracks that can be captured on film.
- Another problem is that the gamma radiation (as shown in the diagram) is not directed at the camera itself.
- Beta particles are easily deflected by matter, and so won't form smooth curves.
- Beta particles have paths with radii much smaller than those of alpha particles.

8(a)

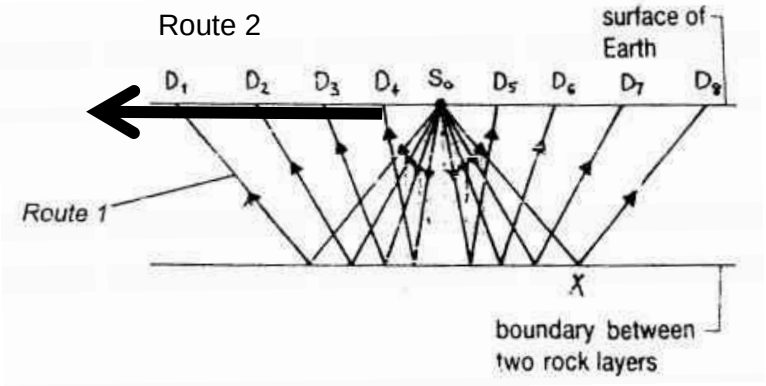


- L waves are the most destructive: so they have the largest amplitude.
- P waves are the fastest: so they arrive before the other 2 waves.

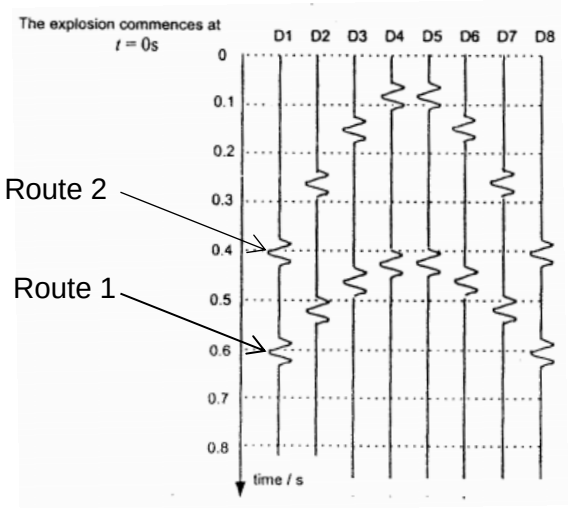
(b)

- Just above B: the rocks are very dense.
- Just below B: the material has low density. May not be rock.

(c)(i)



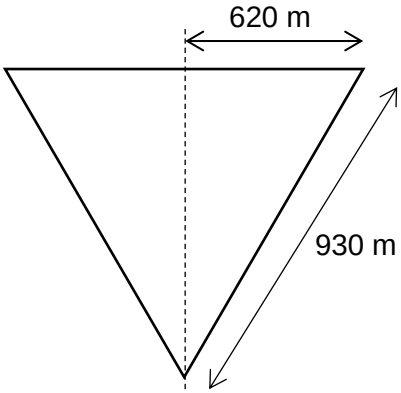
(ii)



(iii) S_0D_8 = speed x time
= 3100 x 0.4
= 1240 m

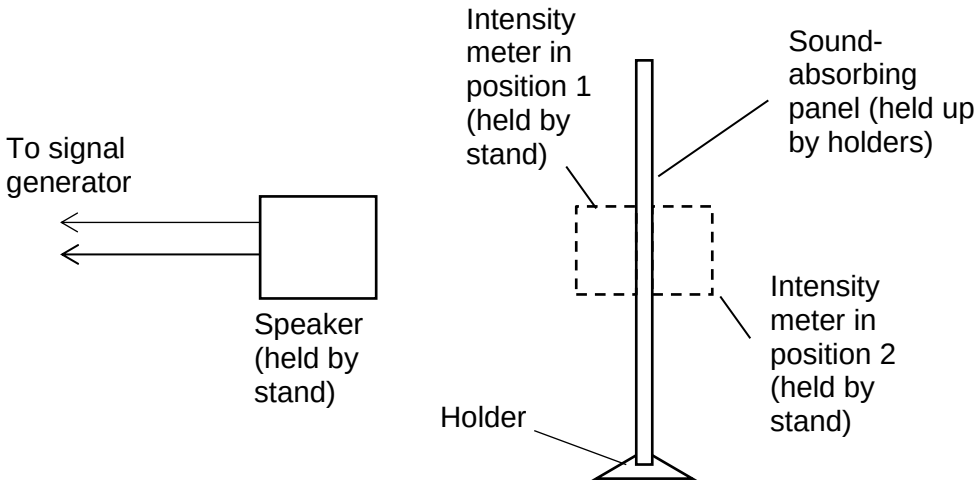
S_0XD_8 = 3100 x 0.6
= 1860 m

(iv)



Depth = $\sqrt{930^2 - 620^2}$
= 690 m

9 Diagram



Procedure

- Hold up a large piece of sound-absorbing panel vertically using holders. Measure and record the thickness of the panel, *d*, using micrometer.
- Place a speaker in front of the panel so that sound is directed perpendicularly at the centre of the panel.
- Place the intensity meter in position 1, just in front of the centre of the panel.
- Switch on the signal generator, and adjust the volume to an appropriate level. Measure I_0, the intensity of the sound incident on the panel.
- Without changing the loudness of the sound, place the intensity meter in position 2, just behind the centre of the panel. Measure I_t, the intensity of the sound transmitted through the panel.

- Calculate and record $T = \frac{I_t}{I_0}$.
- By using panels of different thicknesses, vary d to get more values of T.
- Since $T = ad^n$

  $\lg T = n \lg d + \lg a$

  Plot a graph of lg T vs lg d. Then n = gradient, and $a = 10^{\text{y-intercept}}$

Control variables

1) The frequency of the sound should be kept constant, as T might be dependent on it. This can be ensured by keeping the same frequency setting on the signal generator throughout the whole experiment.
2) T might also be dependent on I_0, so the loudness of the sound should be kept constant. This can be ensured by keeping the voltage supplied to the signal generator constant, and also the distance between the speaker and the panel constant. The distance can be measured with a measuring tape.
3) The positions of the intensity meter will affect the readings of I_0 and I_t, and so should be kept the same. This can be done by marking out the positions of the stand holding the meter on the floor.

Accuracy

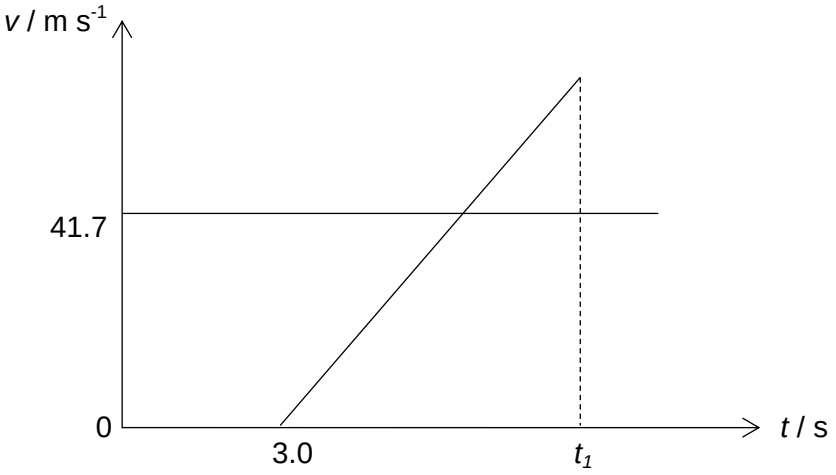
1) The panel should be large enough to prevent the sound from reaching the intensity meter in position 2 by going around the sides of the panel.
2) The sound should be incident on the centre of the panel incidentally, and not at an angle. This can be ensured by holding a rope from the speaker to the centre of the panel, and getting an assistant to check that the rope is perpendicular to both the speaker and the panel. The intensity meter should be placed at the position where the rope meets the panel.
3) As the range of human hearing ranges from 20 Hz to 20,000Hz, the value of T can be measured for different parts of the audible range to see if it varies.

Safety

1) The holders holding up the panel must be stable enough to prevent the panel from collapsing.
2) If it is intended to use a very loud sound for the experiment, ear plugs should be worn to protect the hearing.

VJC 2016 PRELIM H2 P3 (*Suggested Solutions*)

1(a)



Note: 150 km h^{-1} = 41.7 m s^{-1}

(b) Motorcycle overtakes car: both have travelled the same distance.
Areas under the 2 graphs are equal.

Using $v = u + at$, maximum speed of motorcycle = $a(t_1 - 3.0)$

$\frac{1}{2} a(t_1 - 3.0)^2 = 41.7\ t_1$
$\frac{1}{2} (12)(t_1 - 3.0)^2 = 41.7\ t_1$

Solving, t_1 = **12 s** (reject the answer which is less than 3.0 s)

(c)(i) Same speed: using $v = u + at$,

$41.7 = 0 + 12t$
$t = 3.475$ s

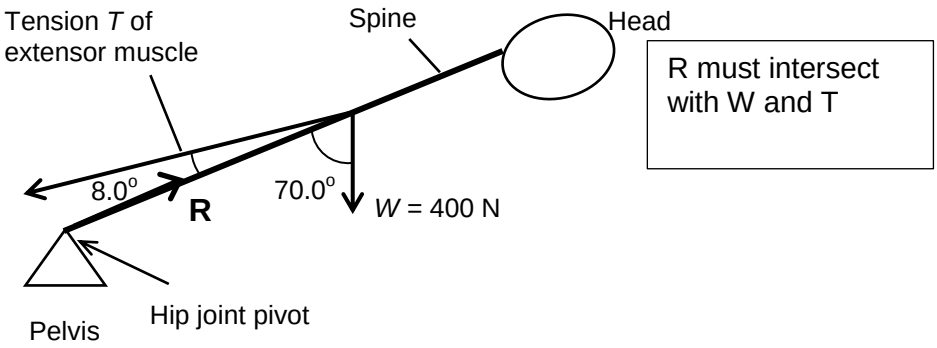
So same speed occurs at 3.475 + 3.0 = 6.475
≈ **6.5 s**

(ii) Before 6.5 s, car is faster than motorcycle: separation increases.
After 6.5 s, car is slower than motorcycle: separation decreases.
∴ Largest separation occurs at 6.5 s

(Remember: the car travels for 6.475 s while the motorcycle travels for only 3.475 s)

Largest separation = distance travelled by car – distance travelled by motorcycle
$= (41.7 \times 6.475) - (\frac{1}{2} \times 12 \times 3.475^2)$
= **198 m**

2(a)



(b) As R, W and T intersect at a point, taking moment about that point would mean that there is no net moment. This would allow the person to be in rotational equilibrium.

(c)(i) R, W and T must form a closed triangle so that there is no net force acting on the body.

(ii)

Using sine rule:

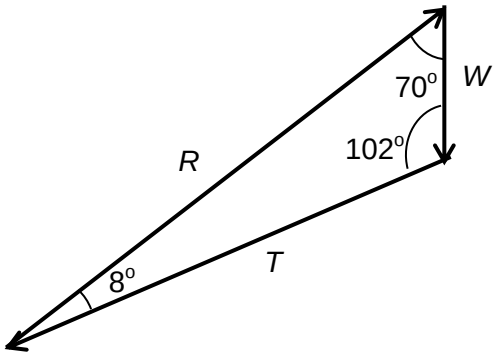
$$\frac{W}{sin8^o} = \frac{R}{sin102^o} = \frac{T}{sin70^o}$$

$$\frac{400}{sin8^o} = \frac{R}{sin102^o} = \frac{T}{sin70^o}$$

Solving for R and T we get:

R = **2.8×10^3 N**

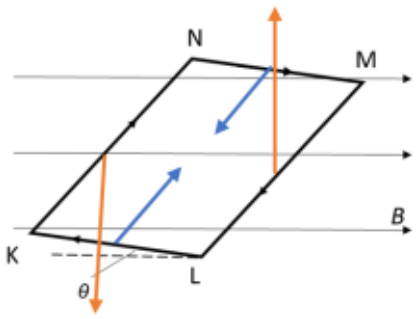
T = **2.7×10^3 N**



(d) When the spine is almost vertical, the moment due to the weight about the pivot is reduced to a much smaller value. For rotational equilibrium, the counteracting moment due to the tension *T* in the extensor muscle is also small. So *T* will also be small, and so the back muscle won't be strained.

3(a) Magnetic Flux Density is the force per unit current, per unit length experienced by a wire at right angles to the magnetic field.

(b) (i)



(ii) $F_{KN} = NBIy$

Taking moments about the mid-point of LM,

$\tau = xF_{KN}\cos\theta = NBIyx\cos\theta$

(c) (i) At rotational equilibrium, the sum of torques must be zero.

$$\tau_{\text{coil}} = \tau_{\text{spring}}$$
$$NBIA = k\phi$$
$$\phi = \frac{NBA}{k} I$$
$$\therefore \phi \propto I$$

(ii) From (b)(ii), in a uniform field, the torque applied on the side of the coil depends on the cosine of the angle to the field as it rotates and hence does not vary linearly.
However, in a radial field, the magnetic forces on the coil are always perpendicular to the plane of the coil and the torque will be independent of the position of the coil. So, a linear relationship between the current and the magnetic flux density, as seen in (c)(i), is obtained as required by a galvanometer.

(iii) Either by increasing the number of turns, the strength of the magnetic field applied, a larger cross-sectional area of coil or decreasing the spring constant of the spring.

4 (a) From '$q = It$', total charge flow in 5 hours,
$q = 2.1 \times 5 \times 3600$
$= 3.78 \times 10^4$ C

The total number of electrons passing through the battery in 5 hours,

$N_e = \frac{q}{e}$
$= 3.78 \times 10^4 / e$
$=$ **$\underline{2.4 \times 10^{23}}$**

(b) (i) Recall " $P = V^2/R$ "
resistance of a headlight, $R = V^2/P$
$= 12^2/48$
$=$ **$\underline{3.0\ \Omega}$**

(ii) Recall " $R = \rho l/A$ "

$$l = \frac{RA}{\rho}$$
$$= \frac{R\pi r^2}{\rho}$$
$$= \frac{3\pi(9.0\times10^{-5})^2}{7.9\times10^{-7}}$$
$=$ **$\underline{9.7 \times 10^{-2}\ \text{m or } 9.7\ \text{cm}}$**

Comment: For such a long filament to fit inside the small bulb of a headlight, the filament would have to be coiled up.

(iii) The 6 lamps are in parallel.
Effective resistance of the 6 lamps, $R_{\text{lamps}} = (2/3 + 4/24)^{-1}$
$= 1.2\ \Omega$

The total resistance of the circuit
R_{total} = 1.2 + 0.026
= 1.226 Ω

Thus, the current in battery, $I = V/R_{total}$
= 12/1.226
= **9.8 A**

(iv) When S_1 is closed (another parallel branch has been introduced into the circuit), the total effective resistance of the circuit will decrease (to below 1.226 Ω). So the total current supplied by the battery will increase (to higher than 9.8 A).

So the p.d. across the internal resistance will increase, and using the potential divider principle, the p.d. across each lamp will decrease.

So the power delivered to each lamp will decrease and each lamp becomes less bright.

5(a) (i) The phase difference between two waves arriving at a point is the difference in fraction of a cycle each wave leads or lags the other by.

(ii) When two waves are coherent, the have constant phase difference.

(b) (i)

$$I \propto A^2$$
$$I = kA^2$$
$$\therefore A_1 = \sqrt{I/k}$$
$$\therefore A_2 = \sqrt{3I/k}$$

As the two waves have zero path difference at point A and are in phase when they are produced at the speakers, constructive interference happens at A.

$$A_A = A_1 + A_2$$
$$I_A = kA_A^2$$
$$= k(\sqrt{I/k} + \sqrt{3I/k})^2$$
$$= k(I/k + 3I/k + 2\sqrt{3}I/k)$$
$$= 7.5I$$

(ii)

$$\lambda = \frac{v}{f} = \frac{336}{2800} = 0.120\ \text{m}$$

$$\Delta x = 4.02 - 3.72 = 0.3\ \text{m}$$
$$= 2.5\,\lambda$$

Since the path difference is exactly 2.5 wavelengths, the 2 waves arrive out of phase resulting in destructive interference. So a minimum signal is detected at B.

(iii) At point B, the path difference is 0.3 m.

When the wavelength is equal to $\frac{0.3}{(n+\frac{1}{2})}$ where *n* is an integer starting from zero, destructive interference occurs, corresponding to minima.

When the wavelength is equal to $\frac{0.3}{(n)}$, constructive interference occurs, corresponding to maxima.

As the frequency increases, the wavelength decreases. Hence a series of maxima and minima can be heard as the wavelength is gradually decreased from 0.12 m.

(c) (i) Using the geometry of the first order bright dot to calculate,

$$\tan\theta = \frac{107.3 - 72.7}{200}$$

$$\theta = 9.82^{\circ}$$

Using the equation for diffraction grating,

$d\sin\theta = n\lambda$ where $n = 1$

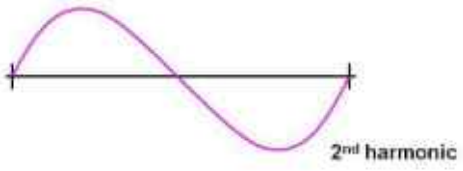
$$\lambda = \frac{1\times10^{-3}}{250}\sin(9.82)$$

$$= 682\ \text{nm}$$

(ii) Instead of a localized bright maxima, an extended maxima fringe of some width is observed. (due to each wavelength diffracting by a slightly different angle)

(iii) Blue light has a shorter wavelength than red light and hence according the to the equation for diffraction grating, $d\sin\theta = n\lambda$, the relative angle each maxima is closer together, resulting in more fringes visible.

(d) From the information given, $L = \lambda$, hence it is oscillating at 2nd harmonic.



$$\lambda = L$$

$$\frac{v}{f} = L$$

$$\therefore v = 100L$$

At its next mode that fulfils the criteria it is vibrating at is the 6th harmonic.



$$\lambda = \frac{L}{3}$$

$$f = \frac{v}{\lambda}$$

$$= \frac{100L}{L/3}$$

$$= 300 \text{ Hz}$$

6(a)(i) Max KE = eV_s
= $(1.6 \times 10^{-19})(1.7)$
= 2.72×10^{-19} J

Work function, ϕ = hc/λ - Max KE
= $(6.63 \times 10^{-34})(3.00 \times 10^{8})/(420 \times 10^{-9})$ - 2.72×10^{-19}
= 2.01×10^{-19} J

Threshold wavelength, λ_T = hc/ϕ
= $(6.63 \times 10^{-34})(3.00 \times 10^{8})/(2.01 \times 10^{-19})$
= **990 nm**

(ii) The existence of this threshold wavelength cannot be explained by the classical wave theory of light. This leads to the photon theory of light, which can explain why light must be below a certain maximum wavelength for photoemission to occur.

(b)(i) Emission spectra lines are due to the electromagnetic radiations emitted when electrons within the atom lose energy. These electromagnetic radiations are in the form of photons whose energy is *hf* where *f* is the frequency of the radiation.
Since the emission spectral lines are discrete with well-defined frequencies, this implies that the electrons lose energies in discrete amounts.
This is only possible if electrons transit between discrete energy levels in an atom.

(ii) When the vapour in a discharge tube is at low pressure, the ions are so far apart from each other that their energy levels will not be interacting with each other to form energy bands, therefore their energy levels will remain discrete.

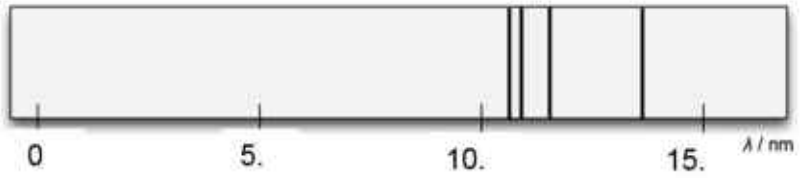
(c)(i) $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} \Rightarrow \lambda_{\text{emission}} = \frac{hc}{\Delta E}$

Shortest wavelength $= \frac{hc}{(121.9 - 4.9)e} = 10.6$ nm (3 s.f.)

Longest wavelength $= \frac{hc}{(7.6 - 4.9)e} = 460$ nm (3 s.f.)

(ii) Number of spectral lines occurs between two levels, number of ways to produce spectral lines is $^5C_2$. Number of spectral lines is **10**.

(d)



10.6 nm, 10.8 nm, 11.4 nm, 13.6 nm

(e)(i) 1. Ionisation energy is the energy required to remove (to infinity) the outermost electron in an atom.

2. 122 eV

(ii) Work function is the energy to remove delocalised electrons in the conduction band to infinity.

Ionisation energy is the energy to remove electrons from the ground state to infinity.

The conduction band occupies energies higher than the ground state of an isolated atom.

Therefore less energy is required to remove delocalised electrons.

7(a)(i) The activity is the number of nuclear disintegrations per unit time.

(ii) The decay constant is the probability of decay per unit time of a radioactive nucleus.

(iii) The half-life is the time taken for half the number of radioactive nuclei in a sample to decay.

(b)(i) For α-decay: $^{214}_{83}\text{Bi} \rightarrow {}^{210}_{81}\text{Tl} + {}^{4}_{2}\text{He}$

For β-decay: $^{214}_{83}\text{Bi} \rightarrow {}^{214}_{84}\text{Po} + {}^{0}_{-1}\text{e}$

(ii) Total rest-mass on LHS of equation = 213.9987 *u*
Total rest-mass on RHS of equation = 209.9901 *u* + 4.0015 *u* = 213.9916 *u*

Difference in mass = 0.0071 *u*

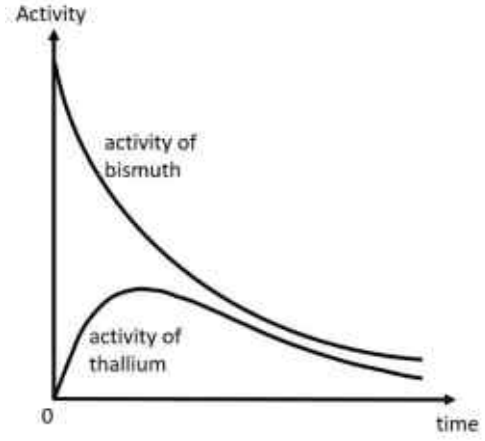
Change in rest-mass energy:

$$\Delta E = \Delta m c^2$$
$$= (0.0071)(1.66\times10^{-27})(3.00\times10^{8})^2$$
$$= \mathbf{1.06 \times 10^{-12}\ J}$$

(iii) The 2 sets of decay products (from the 2 decay processes) are different and have different masses and/or different binding energies per nucleon, leading to different mass defects for both reactions.

So the total amount of energy released for each process will also be different.
It follows that the γ photons emitted will have different energies.

(c)(i) & (ii)



(d)(i) 214 g of Bi contains 1 mol of atoms = N_A = 6.02 × 10^{23} atoms

2.0 μg contains $\frac{2.0\times10^{-6}}{214}\times6.02\times10^{23}$

≈ 5.6 × 10^{15} atoms

(ii) Recall $A = \lambda N$

λ = (3.3 × 10^{12}) ÷ (5.6 × 10^{15})

= **5.9 × 10^{-4} s^{-1}**

(iii) $t_{1/2} = \frac{0.693}{\lambda}$

$= \frac{0.693}{5.9\times10^{-4}}$

= **1.2 × 10^3 s**

(iv) $A = A_o e^{-\lambda t}$

$\frac{3.3\times10^{6}}{3.3\times10^{12}} = \exp\left[-(5.89\times10^{-4})t\right]$

t = **2.4 × 10^4 s**

(e) When the high energy β-particles impact the lead walls, they will lose kinetic energy and decelerate.

The amount of energy lost by a β-particle may be large enough to correspond to X-ray radiation. (known as bremsstrahlung X-rays)

Candidate's Name …… CTG ……

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2016

PHYSICS **9646/1**
HIGHER 2 **26 August 2016**
Paper 1 Multiple Choice **Friday**
1 hour 15 minutes

Additional Materials:
Optical Mark Sheet

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READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

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

Write your name and CTG on the Optical Mark Sheet in the spaces provided.
Shade your NRIC in the space provided.

There are **forty** 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 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.

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}
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	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
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	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 A boat changes its velocity from 16 m s^{-1} due north to 12 m s^{-1} due east.

What is its change in velocity?

A 4 m s^{-1} at direction of 37° east of north

B 4 m s^{-1} at direction of 53° west of north

C 20 m s^{-1} at direction of 37° east of south

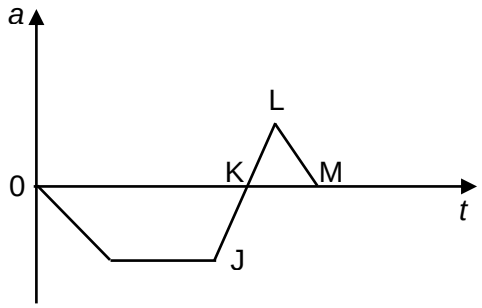
D 20 m s^{-1} at direction of 53° west of south

2 A student uses an analogue mass balance to measure mass. The mass balance is marked for every 0.2 kg but has a zero error of 0.4 kg. The student is not aware of this zero error and writes down a reading of 2.2 kg.

Is this reading accurate and precise?

	accurate	precise
A	no	no
B	no	yes
C	yes	no
D	yes	yes

3 A car starts from rest and travels along a straight road. The graph shows the variation with time *t* of its acceleration *a*, during part of the journey.



At which points on the graph does the car have its greatest speed and greatest displacement?

	greatest speed	greatest displacement
A	J	K
B	K	M
C	L	L
D	M	K

4 A motorist travelling at 13 m s^{-1} approaches a traffic light which turns red when he is 25 m away from the stop line. His reaction time (i.e. the interval between seeing the red line and applying the brakes) is 0.70 s and he brakes at a rate of 4.5 m s^{-2}. How far from the stop line will he stop, and on which side of it?

A 2.9 m behind the line

B 2.9 m beyond the line

C 4.0 m behind the line

D 4.0 m beyond the line

5 Newton's third law of motion concerns action and reaction forces.

Which pair of forces is not a valid example?

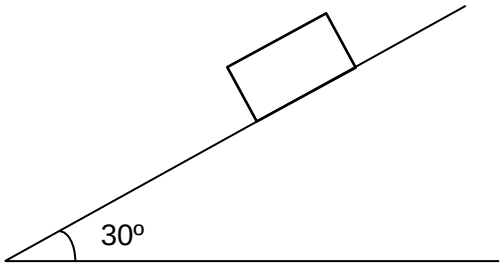
A The gravitation forces of attraction between the Earth and the satellite orbiting around the Earth

B The forces of repulsion between the horse magnet and a wire carrying current placed in between the horse magnet

C Upthrust on the block immersed in water and the force exerted by the block on water

D Weight of the book and the normal force from the floor on the book which is placed on the floor

6 A 1.0 kg block is placed on the slope which is inclined at angle of 30º as shown in the figure.

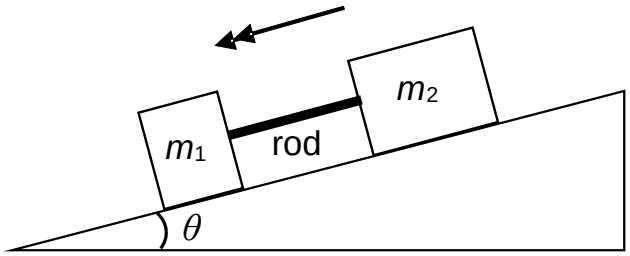


Assuming that the frictional force acting on the block is 2.5 N, what is the downward acceleration along the slope after the block is released from rest?

A 2.41 m s^{-2} **B** 4.91 m s^{-2} **C** 6.00 m s^{-2} **D** 9.81 m s^{-2}

7 Two masses m_1 and m_2 are connected by a light rod as shown.

The blocks are moving with acceleration *a,* down a smooth slope that is inclined at angle θ. What is the tension in the rod?

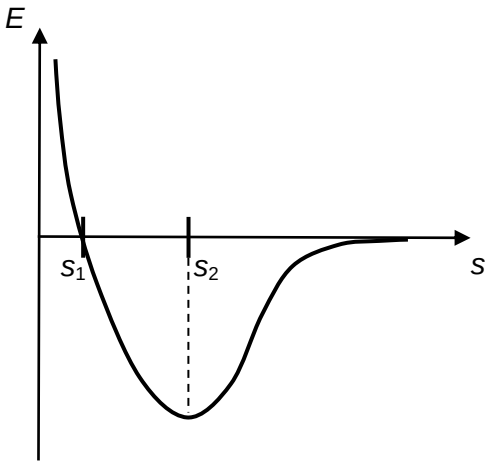


A $m_1 a$ (sin θ) **B** $(m_1 - m_2)a$ **C** $(m_1 + m_2)a$ **D** zero

8 A man sitting in a train carriage observes that a pendulum hanging from the ceiling makes an angle of 30º to the vertical. What is the acceleration of the train?

A 4.9 m s^{-2} **B** 5.7 m s^{-2} **C** 8.5 m s^{-2} **D** 9.8 m s^{-2}

9 The mutual potential energy E of two molecules separated by a distance s is shown in the graph below.



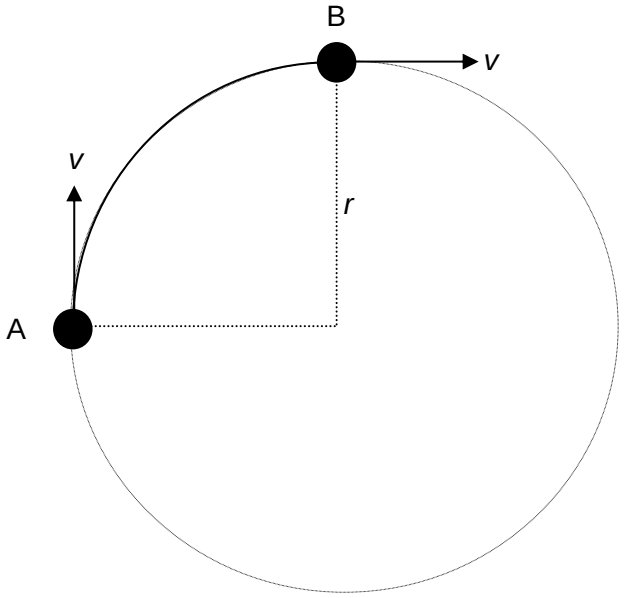
Which of the following correctly describes the forces between the molecules?

	attractive for	repulsive for
A	$s < s_2$	$s > s_2$
B	$s > s_2$	$s < s_2$
C	$s < s_1$	$s > s_1$
D	$s > s_1$	$s < s_1$

10 The power delivered by an engine to a train travelling at a constant speed of 45 m s^{-1} is 2.0 MW. What is the resistive force it experiences?

A 0 N **B** 9.9×10^2 N **C** 2.2×10^4 N **D** 4.4×10^4 N

11 A ball of mass *m* attached to a rope is swung in a horizontal circle of radius *r*. What is the work done on the ball by the tension in the rope as it moves from A to B?



Top view

A zero

B $m\,g\,r$

C $m\,v^2$

D $\frac{1}{2}\pi m\,v^2$

12 A small ball is moving in a vertical circle at constant speed. The magnitude of the resultant force acting on the ball

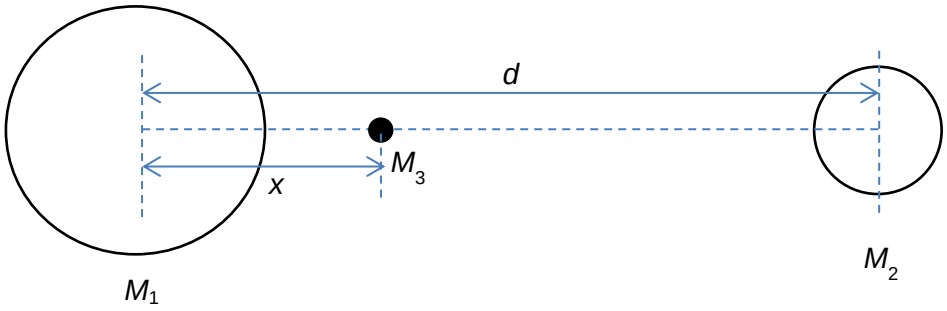
A is largest at the bottom of the circle and smallest at the top of the circle.

B is smallest at the bottom of the circle and largest at the top of the circle.

C is the same at the top and bottom of the circle.

D is zero at the top of the circle.

13 Two planets of masses M_1 and M_2 are a distance d apart. A third planet M_3 is found at a distance x from M_1. Which of the following correctly shows the expressions to determine the resultant gravitational force and gravitational potential energy of M_3?



	resultant gravitational force	gravitational potential energy
A	$\frac{GM_1M_3}{x^2} - \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} - \frac{GM_2M_3}{(d-x)}$
B	$\frac{GM_1M_3}{x^2} + \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$
C	$\frac{GM_1M_3}{x^2} - \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$
D	$\frac{GM_1M_3}{x^2} + \frac{GM_2M_3}{(d-x)^2}$	$\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$

14 A spacecraft has been launched from surface of Planet X into space. When it is at a distance from the planet, the engine is shut down and the spacecraft continues its motion away from the planet. Ignoring the influence of all other celestial bodies, which of the following is **true**?

A The gravitational potential energy of the spacecraft is decreasing.

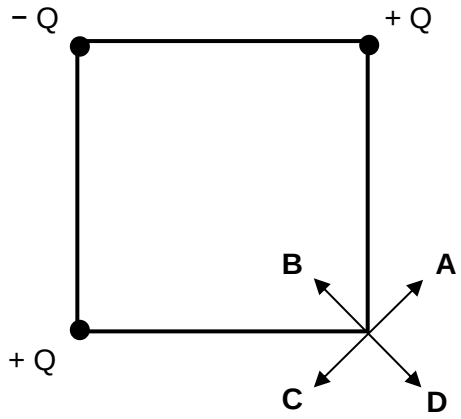
B The spacecraft continues to move with constant velocity.

C The gravitational force experienced by the objects in the spacecraft is zero.

D The gravitational force experienced by the objects in the spacecraft is decreasing in value.

15 The diagram shows three point charges, each of magnitude Q, placed at three corners of a square.

What is the direction of the resultant electric field at the fourth corner?



16 The electric potential of an isolated point charge has magnitude V at a distance of 2.0 m away from the point charge. What is the distance from the charge when the magnitude of electric potential is $\frac{V}{4}$?

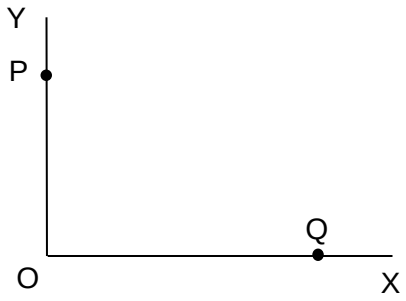
A 4.0 m

B 8.0 m

C 12.0 m

D 16.0 m

17 The diagram shows a flat surface with lines OX and OY at right angles to each other.



A straight current carrying conductor is placed at a position such that the magnetic field at O is found to be in the direction OX.

Which of the following correctly shows the position of the straight conductor and the direction of its current flow?

	position	direction of current flow
A	P	into the plane
B	P	out of the plane
C	Q	into the plane
D	Q	out of the plane

18 An electron is moving along the axis of a current-carrying solenoid.

Which of the following is a correct statement about the electromagnetic force acting on the electron?

A The electromagnetic force acts radially outwards.

B The electromagnetic force acts radially inwards.

C The electromagnetic force acts in the direction of motion.

D No electromagnetic force acts on the electron.

19 A resistor of resistance *R* has power *P* when the current in the resistor is I. What is the resistance of a resistor that has power 2*P* when the current in the resistor is $\frac{I}{2}$?

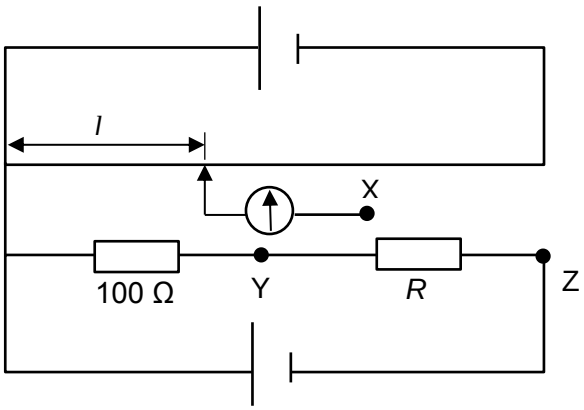
A $\frac{R}{8}$

B $\frac{R}{4}$

C $4R$

D $8R$

20 A circuit which may be used to compare the resistance *R* of an unknown resistor with 100 Ω standard is shown. When X is connected to Y, the distance l from the left end of potentiometer slide wire to the balance point is 400 mm. When X is connected to Z, the distance l from left end of potentiometer slide wire to the balance point is 600 mm.



Which of the following is the value of resistance *R*?

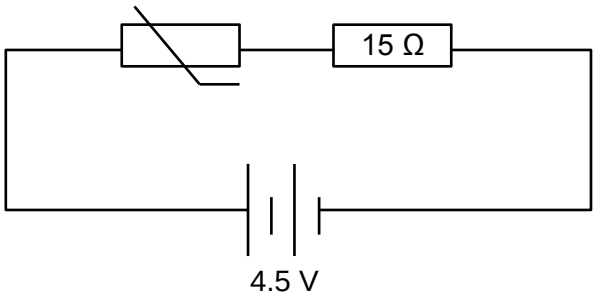
A 50 Ω

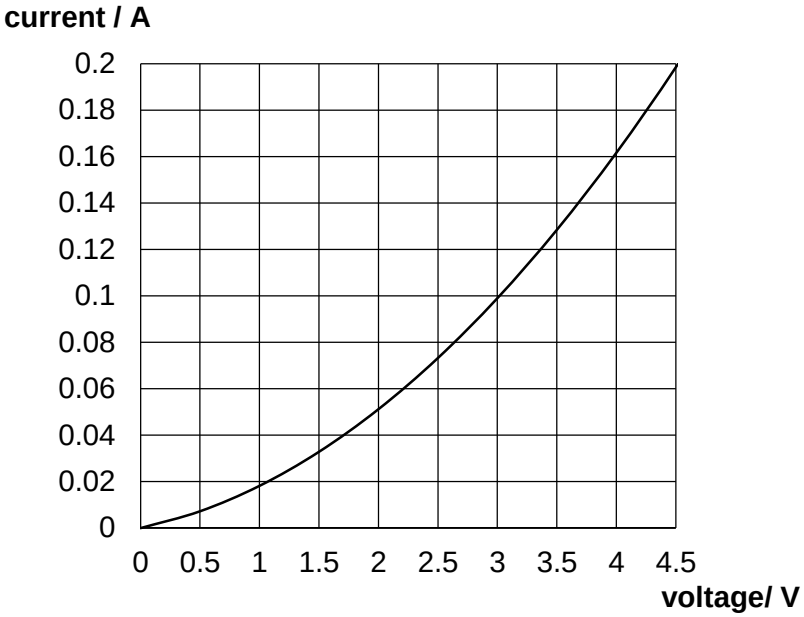
B 100 Ω

C 150 Ω

D 200 Ω

21 A 15 Ω resistor and a thermistor are connected in series to a battery of electromotive force 4.5 V and negligible internal resistance.





The graph above shows the current – voltage characteristic of the thermistor.
What is the current in the circuit?

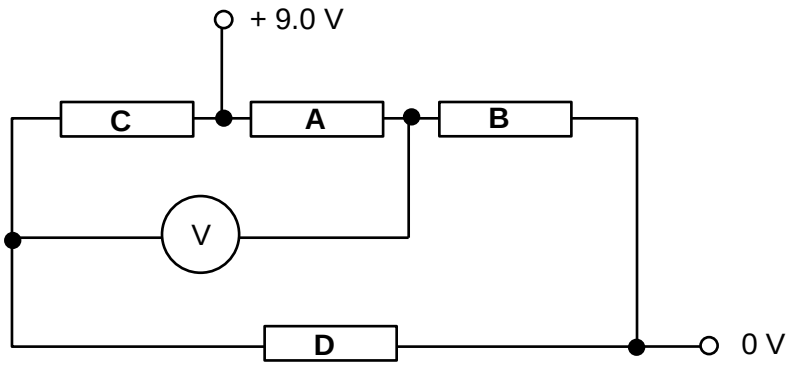
A 0.05 A

B 0.10 A

C 0.15 A

D 0.20 A

22 In the circuit below, the resistance of resistors **A** and **D** is R while the resistance of resistors **C** and **B** is $2R$.



The potential difference between the input terminals is 9.0 V.
What is the reading on the voltmeter?

A 0 V **B** 3.0 V **C** 6.0 V **D** 9.0 V

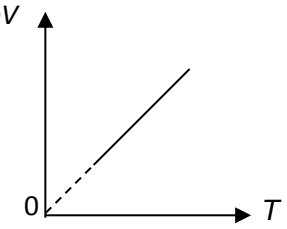
23 Container X contains neon and container Y contains argon. The two containers are identical and the two gases are at the same temperature. The pressure in X is twice that in Y. What is the ratio of the mean kinetic energy of a neon atom to the mean kinetic energy of an argon atom?

[The relative atomic masses of neon and argon are 20 and 40 respectively.]

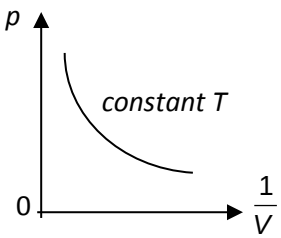
A 0.5 **B** 1 **C** 2 **D** 4

24 Which of the following graphs correctly describes the behaviour of a fixed mass of an ideal gas at pressure p, volume V and thermodynamic temperature T ?

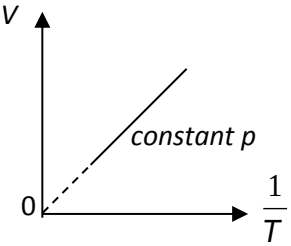
A



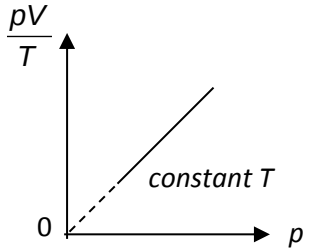
B



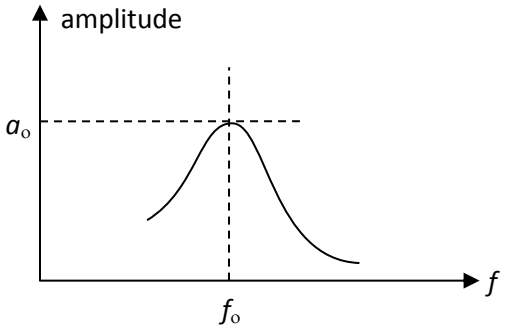
C



D

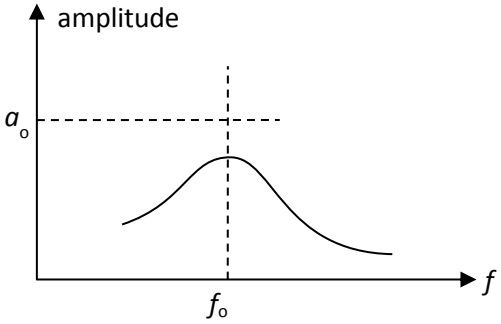


25 A pendulum is constructed from a fixed length of light thread and a spherical, polystyrene bob. It is forced to oscillate in oil at different frequencies *f*. The following diagram shows how the amplitude of its oscillation varies with *f*.

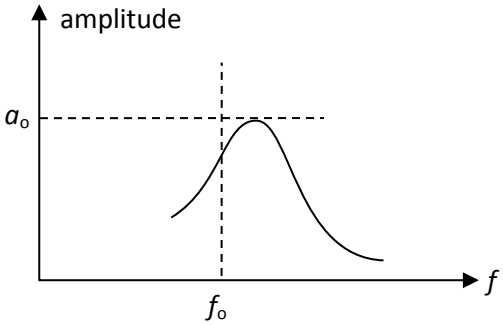


The experiment is repeated in air. Which graph best represents the variation with *f* of the amplitude?

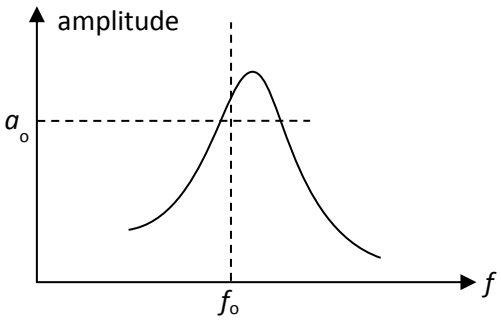
A



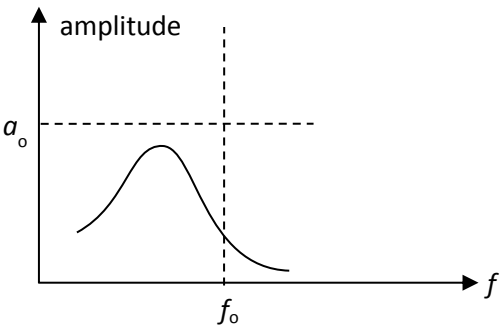
B



C



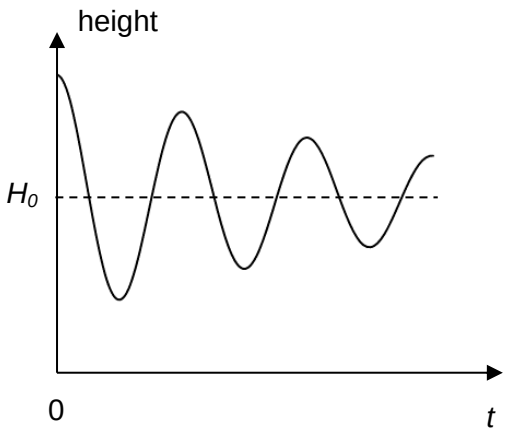
D



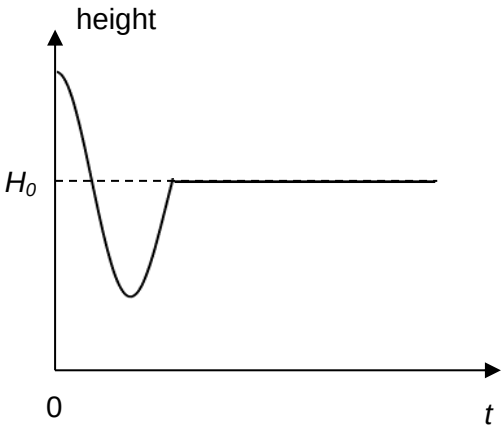
26 The equilibrium height of a car body above the ground is H_0. At time t = 0, the car body is raised slightly to a greater height and released. The tyres of the car may be assumed to remain in contact with the ground throughout and its suspension may be taken to be overdamped.

Which of the following correctly represents the variation of the height of the car body with time?

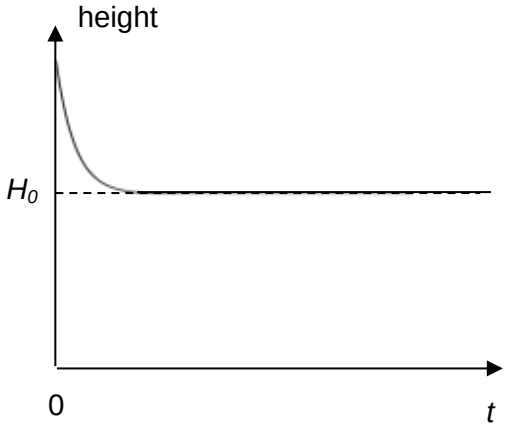
A



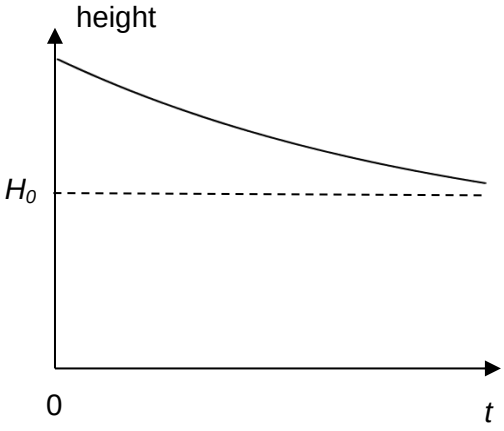
B



C



D



27 Which of the following statements is incorrect about progressive mechanical waves?

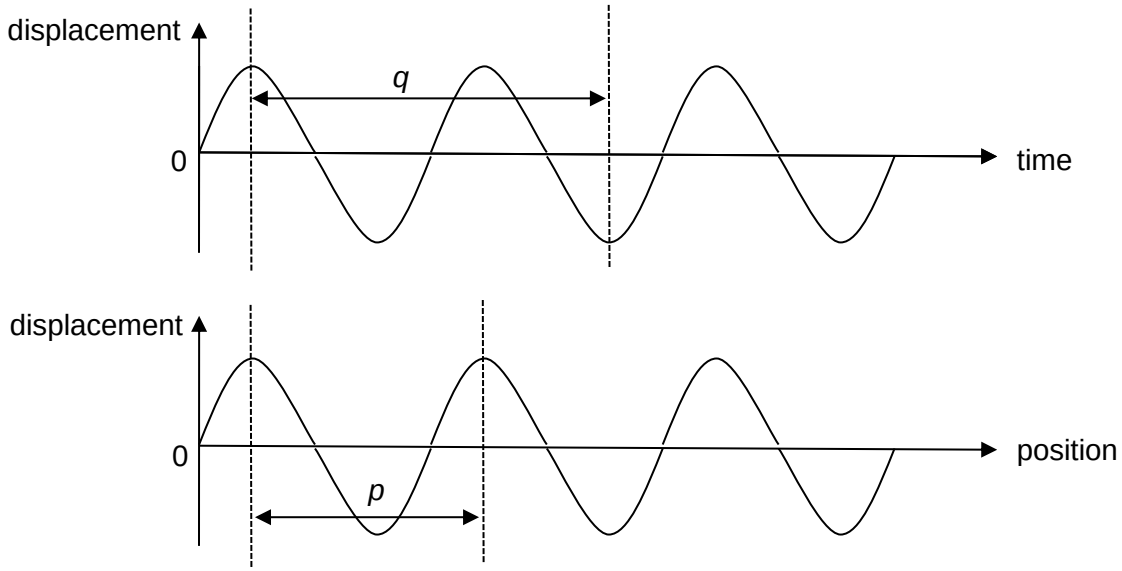
A They propagate due to interaction between the particles of the medium.

B They can be transverse or longitudinal.

C They carry energy as they propagate.

D They can always be polarized.

28 A progressive wave can be represented by the following two graphs.



Which of the following gives the speed of the wave?

A $\frac{q}{p}$ **B** $\frac{p}{q}$ **C** $\frac{2p}{3q}$ **D** $\frac{3p}{2q}$

29 Light of wavelength λ is incident normally on a diffraction grating with slit separation 5λ. What is the angle between the second order maximum and third order maximum?

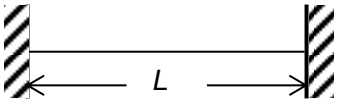
A 11.5°

B 13.3°

C 23.6°

D 36.9°

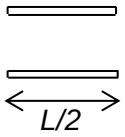
30 The figure below shows a stretched string of length *L*. The speed of waves on the string has the same speed as sound waves in the air. The fundamental mode of oscillation is then set up on the string.



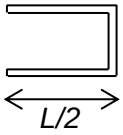
Pipes **A**, **B**, **C** and **D** below have lengths of *L/2*, *L/2, L* and *2L* respectively.

In which pipe will the sound produced by the string cause resonance?

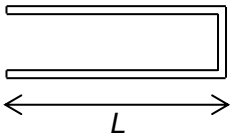
A



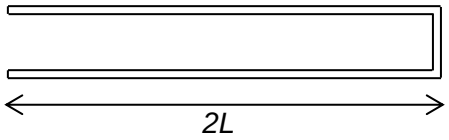
B



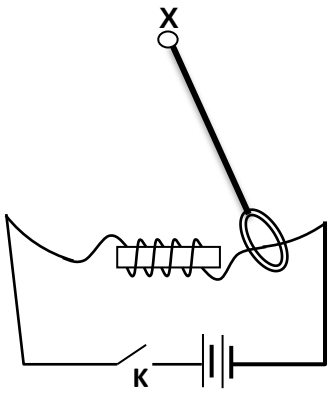
C



D



31 A copper ring is suspended by a long, light rod pivoted at X so that it may swing as a pendulum, as shown. An electromagnet is mounted so that the ring passes over it as it swings.



Switch K is initially open when the ring is set into oscillation. What happens to the motion after switch K is closed?

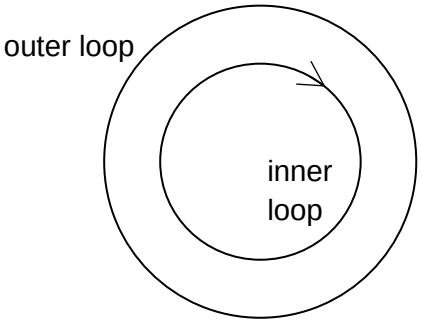
A The periodic time will decrease.

B The oscillation will be heavily damped.

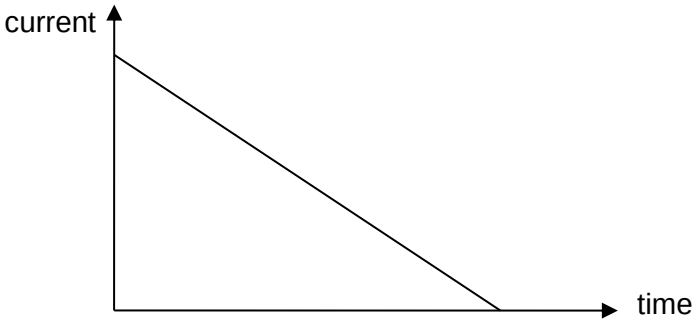
C The amplitude will increase because the ring is repelled by the electromagnet and hence it swings further away.

D The oscillation will continue at constant amplitude since the battery can supply energy to sustain the oscillation.

32 The diagram below shows two concentric loops in the same plane.



The current in the inner loop is flowing clockwise. The variation of the magnitude of the current with time is shown below.



The induced current in the outer loop is

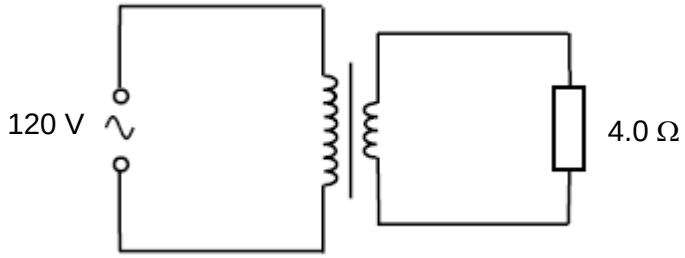
A increasing in the anticlockwise direction.

B constant in the anticlockwise direction and eventually decreases to zero.

C constant in the clockwise direction and eventually decreases to zero.

D decreasing in the clockwise direction.

33 An ideal transformer is used to step down a 120 V a.c. voltage supply. The ratio of secondary turns to the primary turns is 1:20.



What is the current in the primary coil?

A 30 A **B** 6.0 A **C** 1.5 A **D** 0.075 A

34 Electrons in a beam undergo diffraction when incident on a crystalline solid. Given that the order of magnitude of the separation of atoms in the solid is 0.1 nm, what is the estimated speed of an electron in the beam?

A 10^{-24} m s^{-1} **B** 10^{-10} m s^{-1} **C** 10^{5} m s^{-1} **D** 10^{6} m s^{-1}

35 Which of the following observations in the photoelectric effect does not require the use of quantum theory of electromagnetic radiation to explain?

A The existence of a threshold frequency

B The dependence of stopping voltage with frequency of incident radiation

C The relationship between photocurrent and intensity of incident radiation

D The almost instantaneous emission of electrons once radiation of high enough frequency arrives

36 The transition of electrons between three consecutive energy levels in a particular atom gives rise to three spectral lines. The shortest and longest wavelengths of those spectral lines are λ_1 and λ_2 respectively. The wavelength of the other spectral line is

A $\frac{\lambda_1 + \lambda_2}{2}$

B $\lambda_1 - \lambda_2$

C $\frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$

D $(\frac{1}{\lambda_1} - \frac{1}{\lambda_2})^{-1}$

37 What is stimulated emission in LASER?

A An electron from a higher energy level falling to a lower level.

B A charged particle causing light to be emitted from an excited atom.

C A charged particle being emitted from an atom as a result of a high energy photon hitting the atom.

D A photon causing another photon of the same frequency to be emitted from an excited atom.

38 A p-type semiconductor is brought into contact with an n-type semiconductor to form a p-n junction. An application of a p-n junction is to rectify an alternating current. Which of the following statements is false?

A During forward bias condition of a p-n junction, if the applied p.d. overcomes the junction potential, electrons will cross steadily from the n-type side to the p-type side.

B During reverse bias condition of a p-n junction, the width of the depletion region becomes larger as the externally applied p.d. adds to the junction potential.

C During reverse bias condition of a p-n junction, the p-type semi-conductor becomes less negative.

D Under increasingly high reverse bias p.d., current can increase sharply through the p-n junction.

39 The fusion of two deuterium nuclei produces a nuclide of helium and a neutron. It liberates 3.27 MeV of energy.

How does the total mass of the two deuterium nuclei, $M_{reactants}$, compare with the total mass of the helium nucleus and neutron, $M_{products}$?

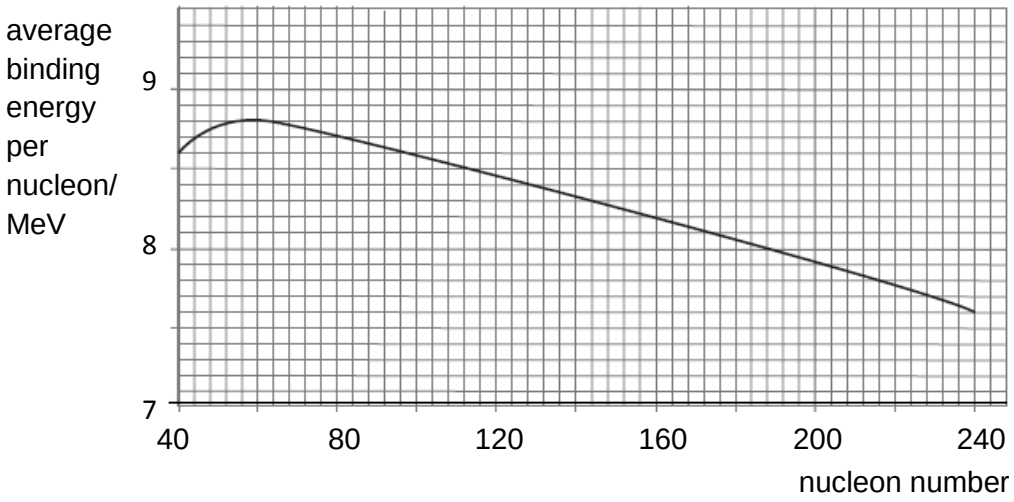
A $M_{reactants}$ is more than $M_{products}$ by 5.8×10^{-30} kg

B $M_{reactants}$ is less than $M_{products}$ by 5.8×10^{-30} kg

C $M_{reactants}$ is more than $M_{products}$ by 5.8×10^{-36} kg

D $M_{reactants}$ is less than $M_{products}$ by 5.8×10^{-36} kg

40 The figure below shows an enlarged portion of a graph indicating how the average binding energy per nucleon of various nuclides varies with their nucleon number.



During the fission of a uranium-236 nucleus, the nucleus splits into two roughly equal parts and

A approximately 200 MeV of energy is released.

B approximately 1800 MeV of energy is released.

C approximately 200 MeV of energy is absorbed.

D approximately 1800 MeV of energy is absorbed.

END OF PAPER

Parent's Signature ……..

Candidate's Name …… CTG ……..…

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2016

PHYSICS **9646/2**
HIGHER 2 **19 August 2016**
Paper 2 **Friday**
Short Structured Questions **1 hour 45 minutes**

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

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READ THESE INSTRUCTIONS FIRST

Write your 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.

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.

Paper 2	
Q1	/10
Q2	/6
Q3	/8
Q4	/10
Q5	/10
Q6	/16
Q7	/12
Penalty	
Total	
	/72
	%

This question paper consists of **22** printed pages.

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}
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	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
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	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions. Show your workings clearly in the spaces provided.

1 A ball is thrown vertically upwards with velocity of 26 m s^{-1}. Fig 1.1 shows the variation with time *t* of the velocity *v* of the ball from the moment it is thrown.

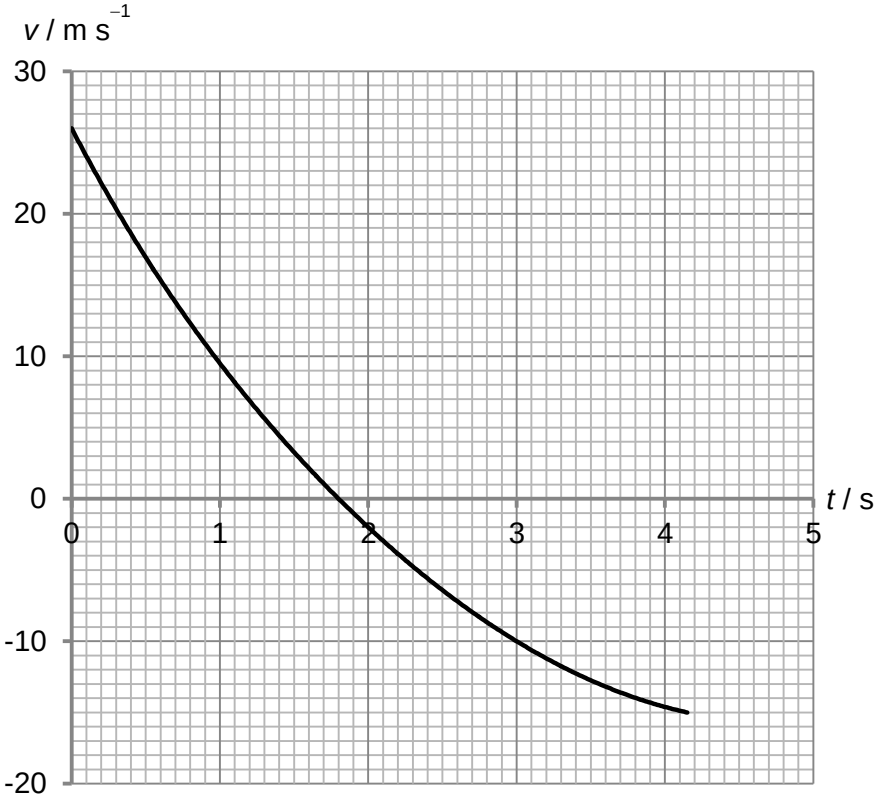

Fig. 1.1

(a) State the time at which the ball reaches its maximum height.

time = ... s [1]

(b) Just after the ball leaves the thrower's hand, it has a downward acceleration of approximately 20 m s^{-2} which is much larger than *g*. Explain how this is possible.

.....

.....

..... [2]

(c) It is found that the acceleration at t = 1.8 s is g. Explain how this is possible.

.....

.....

..... [2]

(d) Sketch the acceleration-time graph and displacement-time graph in Fig. 1.2 for the motion from t = 0 to t = 4 s, following the sign convention taken for the velocity-time graph in Fig. 1.1. The value of g is marked out in the acceleration-time graph. Label other critical values. [5]

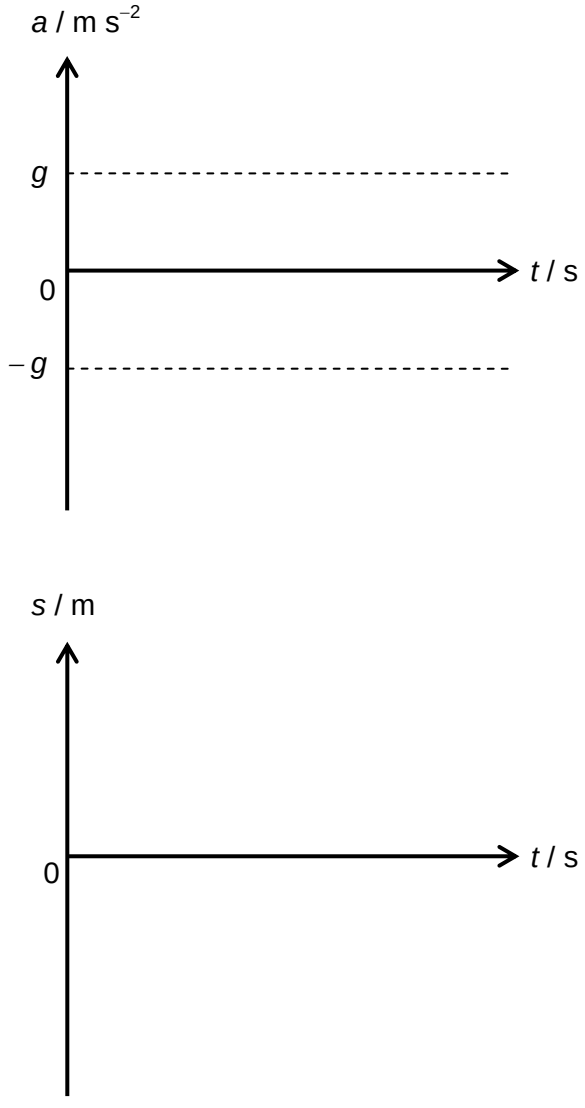

Fig. 1.2

2 A rectangular block of wood of cross-sectional area *A* and thickness *t* floats horizontally in water as shown in Fig. 2.1.

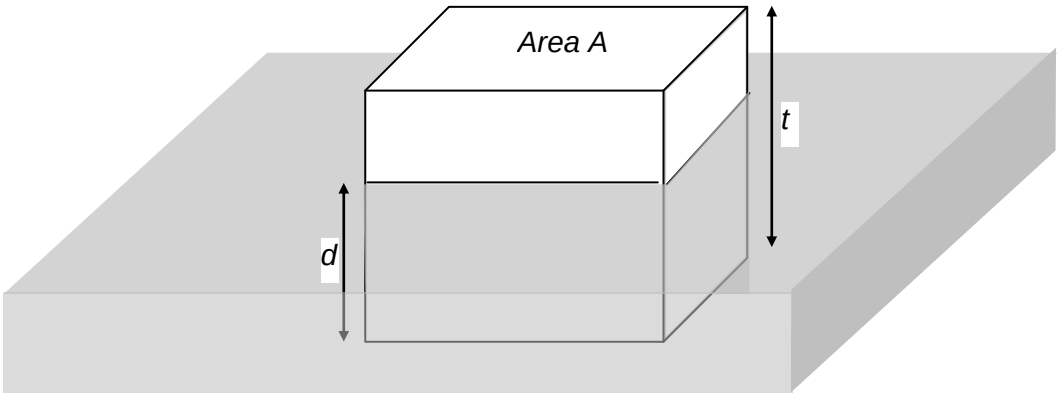

Fig. 2.1

The block floats when its lower face is at a depth *d* in the liquid of density ρ. The block experiences a force *F* on its lower surface as a result of immersion in the liquid.

(a) By considering the water pressure *P* exerted on the lower surface of the block, show that the force *F* is related to the volume *V* of the liquid displaced by the expression

$$F = V \rho g$$

[2]

(b) A 850 kg load tied to a crane is placed on the rectangular block as shown in Fig. 2.2.

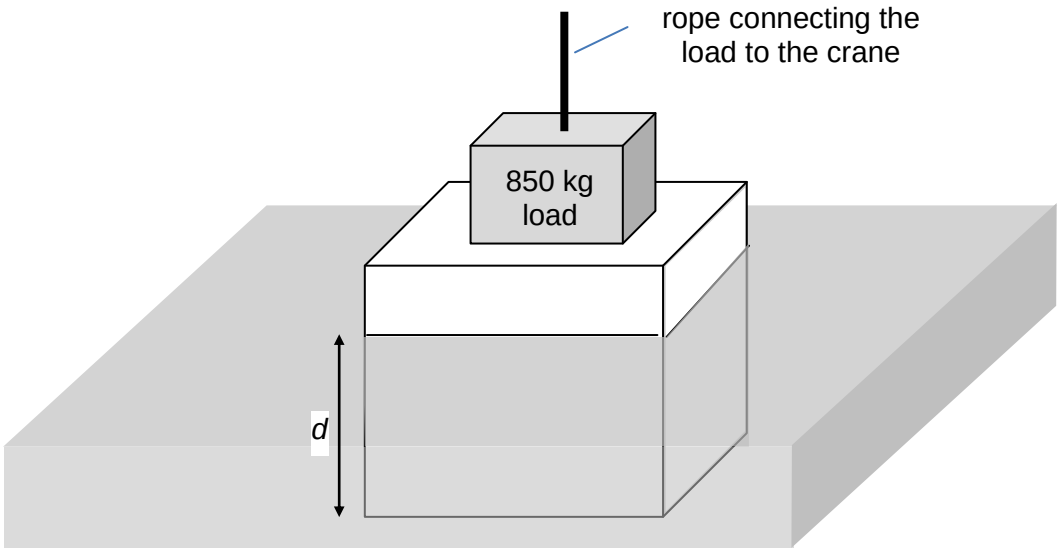

Fig. 2.2

The block is further immersed in the water when the load is placed on it. The value of *d* changes from 70 cm to 95 cm.

Given that the mass of the block is 1500 kg and the density of the liquid is 1000 kg m^{-3}, determine

(i) the surface area *A* of the block,

surface area *A* = ... m^2 [2]

(ii) the tension in the rope.

tension = …… N [2]

3 **(a)** Fig. 3.1 shows a circular open-air swimming pool of radius 15 m.

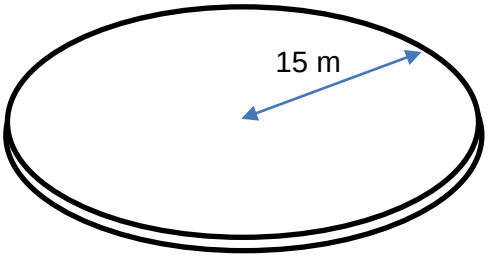

Fig. 3.1

The mass of water in the pool is 6.5×10^5 kg. A heater running at 90 kW is used to maintain the temperature of the water at 30 °C. The specific heat capacity of water is taken to be 4200 J kg^{-1} K^{-1}.

(i) When the heater is switched off for maintenance, the temperature of the water falls slowly to that of the surrounding temperature. Show that the initial rate of fall of temperature is about 0.1 °C per hour.

[3]

(ii) The maintenance usually takes about 3 hours. The rate of fall of temperature depends on the temperature difference between the water and the surrounding. With reference to part **(i)**, suggest why the rate of fall of temperature can be said to be constant during the maintenance.

.....

.....

.....

..... [2]

(b) A cylinder, 0.50 m long and of cross-sectional area *S*, closed at each end, is fitted with a smooth thermally insulating piston, so as to contain the gas in each segment A and B as shown in Fig. 3.2.

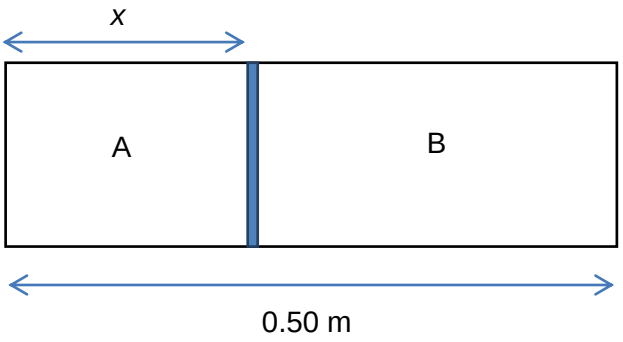

Fig. 3.2

The initial temperature of the gas in both segments is 27 °C and the distance *x* is found to be 0.20 m.

Determine the new distance *x′* when the temperature of the gas in segment A is increased to 250 °C while keeping the temperature of the gas in segment B at 27 °C.

distance *x′* = ……. m [3]

4 A cork, P, floats on the surface of a pond. When a wave travels over the surface, the cork oscillates vertically with simple harmonic motion as shown in Fig.4.1. The cork completes 20 oscillations in 24.0 s and has a total vertical range of 1.6 cm.

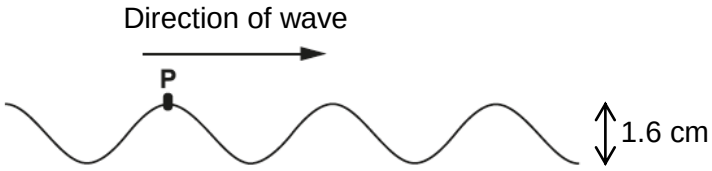

Fig. 4.1

(a) Define *simple harmonic motion*.

……

……

…… [2]

(b) Show that the angular velocity, ω, of oscillation is approximately 5.2 rad s^{-1}. [1]

(c) Given that x is the displacement of the cork from its equilibrium position at time t and that the cork is at the highest point when t = 0, determine the expression for x in cm, taking **downward** as positive. [2]

(d) Determine the time it takes for the cork to move directly downward from a point 0.40 cm above the centre of oscillation to a point 0.30 cm below the centre.

time taken = ……. s [2]

(e) A second cork, Q, also oscillates on the surface at a quarter of a wavelength from P as shown in Fig. 4.2 below.

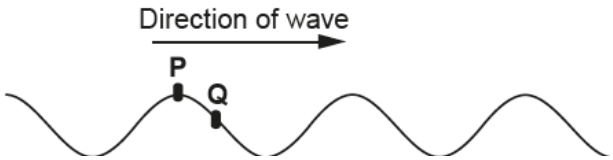

Fig. 4.2

In Fig. 4.3 below, draw the vertical displacements of the two corks during the time interval t = 0 to t = 2.4 s. Use the same axes for both graphs and label them clearly as P and Q. [3]



Fig. 4.3

5 **(a)** Faraday's law of electromagnetic induction predicts that the induced emf, E, in a coil is given by $E = -\frac{dN\phi}{dt}$.

(i) State the physical quantity represented by the symbol ϕ.

..... [1]

(ii) Define *weber*.

..... [1]

(b) In Fig 5.1, the magnet forms the bob of a simple pendulum. The magnet oscillates with a small amplitude along the axis of a 240−turns coil that has a cross−sectional area of 2.5×10^{-4} m^2.

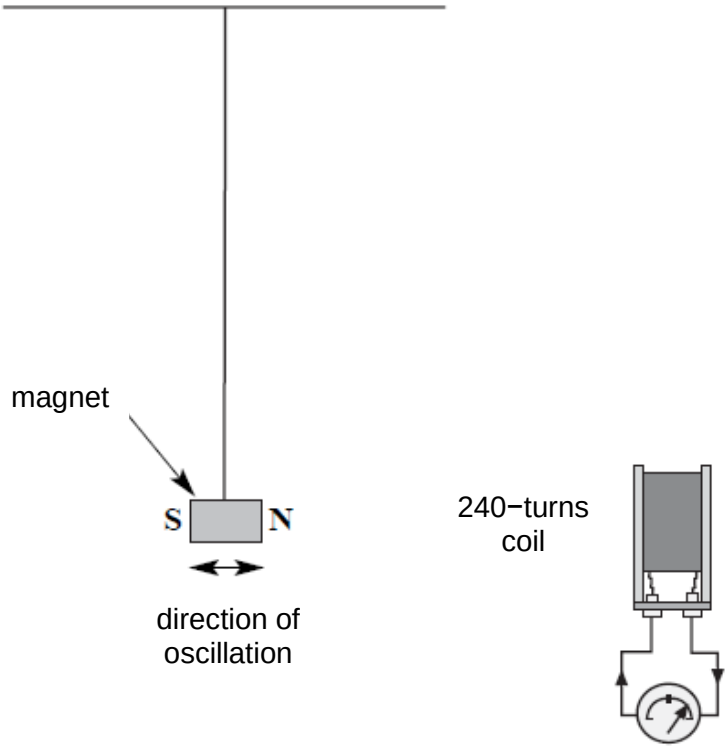

Fig 5.1

Fig. 5.2 shows how the magnetic flux density, *B*, through the coil varies with time, *t*, for one complete oscillation of the magnet.

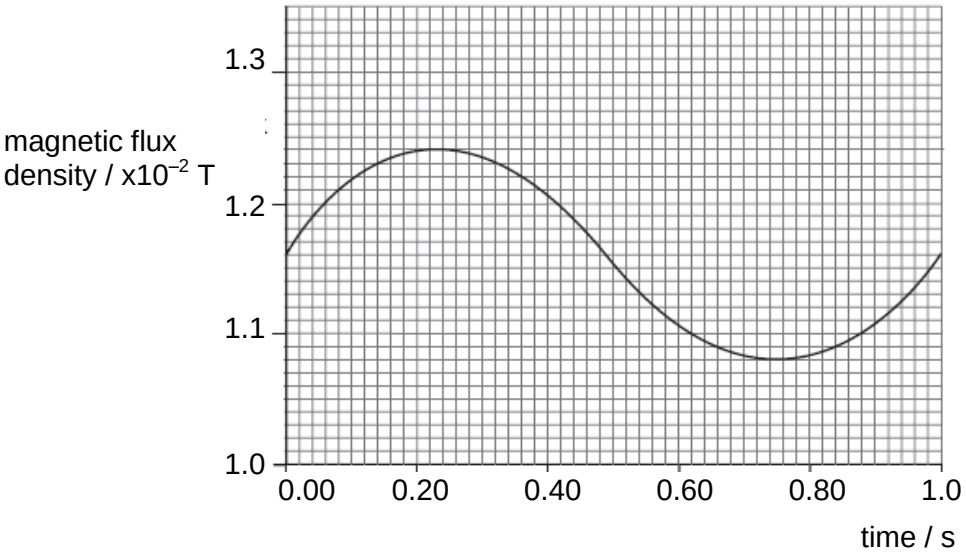

Fig. 5.2

(i) Calculate the maximum e.m.f. induced in the coil.

maximum e.m.f. induced = ……. V [3]

(ii) The frequency of oscillation of the magnet is increased without changing the amplitude.

Explain, using Faraday's law of electromagnetic induction, how the **maximum** e.m.f. induced will change, if any.

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..... [3]

(iii) State **two** other ways of increasing the maximum induced emf.

.....

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..... [2]

6 The decay of a radioactive substance can be represented by the equation

$$A = A_o e^{-\lambda t}$$

where A = the activity of the sample at time t
A_o= the initial activity at time $t = 0$
λ = the decay constant

The half life, $t_{½}$ of the radioactive substance is given by

$$t_{½} = \frac{\ln 2}{\lambda}$$

An experiment was performed to determine the half-life of a radioactive substance which was a β-emitter. The radioactive source was placed close to a detector. The total count for exactly 5 minutes was recorded. This was repeated at 20-minute intervals. The results are shown in Fig. 6.1 below.

time, *t* / minutes	**total count, *C*, recorded in 5 minutes**	**count rate, *R* / minute^{-1}**	**corrected count rate, R_C / minute^{-1}**	**ln (R_C / minute^{-1})**
0	1016	203	183	5.209
20	892	178	158	5.063
40	774	155	135	4.905
60	665			
80	608	122	102	4.625
100	546	109	89	4.489

Fig. 6.1

(a) A correction has been made to the count rate, R, to give the corrected count rate, R_C. Explain why this correction has been made and deduce its value from the table.

.....

.....

.....[2]

(b) **(i)** Complete the table for t = 60 minutes. [2]

(ii) On Fig. 6.2, plot the point corresponding to t = 60 minutes and draw an appropriate straight line through all the plotted points. [1]

(c) Determine the gradient G of your graph.

G = ……[3]

(d) Use your graph to determine the half-life (in minutes) of the radioactive substance used in this experiment.

half-life =..... minutes [2]

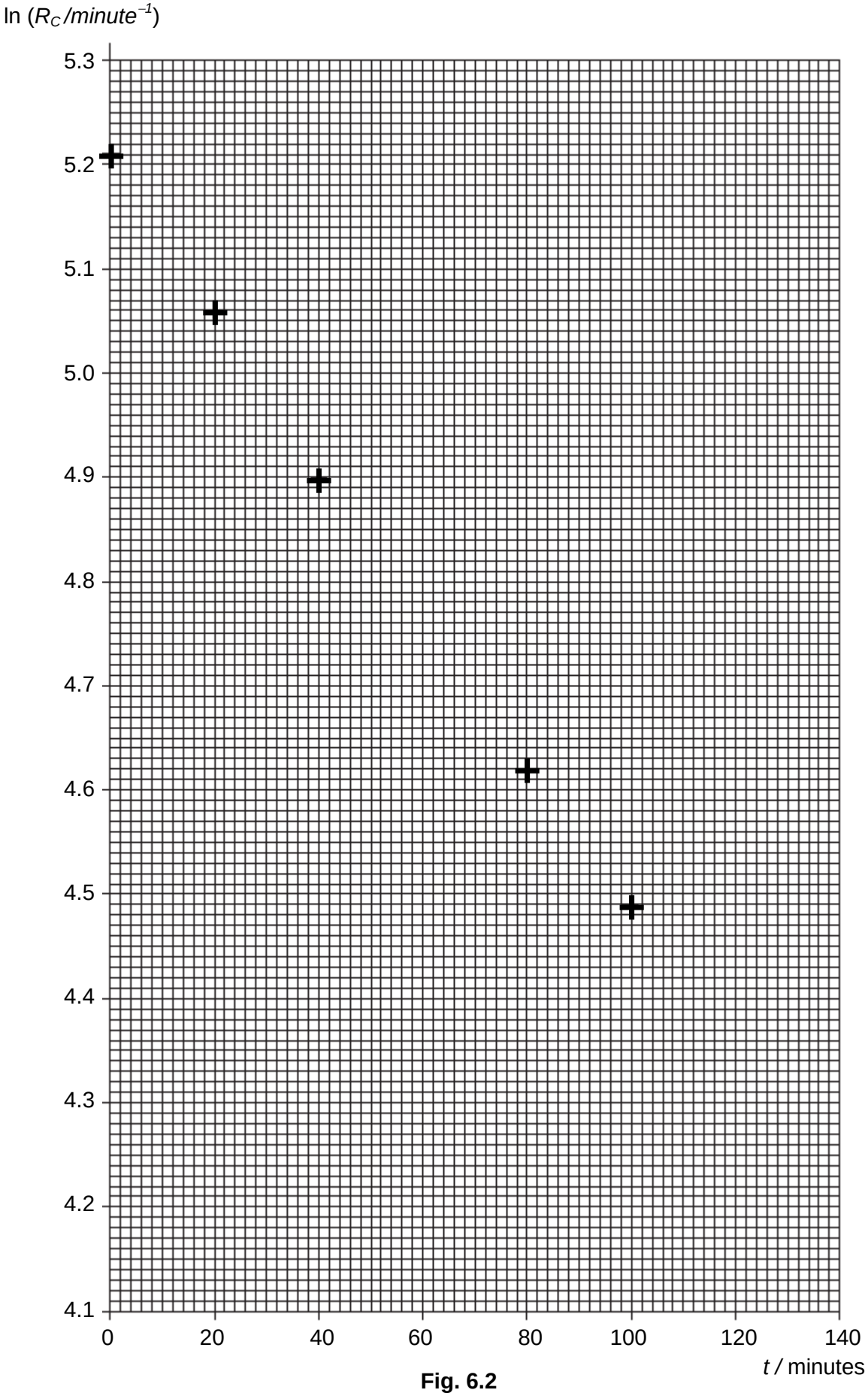
ln (R_C /minute^{-1})
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
0
20
40
60
80
100
120
140
t / minutes

Fig. 6.2

(e) Due to the nature of a radioactive decay, there will be an uncertainty in the total count recorded. State this type of error.

..... [1]

(f) **(i)** It can be shown that the error in the total count *C*, is given by

$$\text{uncertainty in total count } C = \pm\sqrt{C}$$

Using data from the table, calculate the uncertainty in the **smallest** total count, *C*.

uncertainty = …….[1]

(ii) Hence calculate the percentage uncertainty in the **smallest** total count, *C*.

percentage uncertainty = ……% [1]

(iii) Another student performed the same experiment with identical equipment but took total counts over a 1-minute period rather than a 5-minute period. The total count, *C*, at 100 minutes was 110 counts. Estimate the percentage uncertainty in this total count, and hence explain the advantage of using a longer period.

.....

..... [2]

(g) Describe how the straight line graph would change if the radioactive substance has a longer half-life.

.....

..... [1]

7 A **thermistor** is an element composed of semiconductor material which exhibits a large change in resistance proportional to a small change in temperature. The resistance of the thermistor is also dependent on the band gap of the semiconductor material used.

It is suggested that the variation of resistance R of the thermistor with temperature T is given by

$$R = Ae^{-E_g/kT}$$

where A is the initial resistivity of the thermistor (which is a constant),
E_g is the band gap of the semiconductor and
k is the Boltzmann's constant.

Design an experiment to determine the band gap of the material used in the thermistor in the range of temperature from 0 °C to 100 °C.

You may assume that you have the following equipment available, in addition to that normally found in a school science laboratory.

thermistor	beaker
thermocouple	bunsen burner
variable resistor	voltmeter
ammeter	millivoltmeter

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

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the resistance of the thermistor would be measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy and/or reliability of the results obtained.

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- End of Paper -

Parent's Signature ……..

Candidate's Name …….……. CTG …..……..…

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2016

PHYSICS **9646/3**
HIGHER 2 **23 August 2016**
Paper 3 **Tuesday**
Longer Structured Questions **2 hours**

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

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READ THESE INSTRUCTIONS FIRST

Write your name on all the work you hand in.
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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 **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	
Section A	
1	**/12**
2	**/10**
3	**/8**
4	**/10**
Section B	
5	**/20**
6	**/20**
7	**/20**
Penalty	
Total	**/80**

This question paper consists of **24** printed pages.

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}
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	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
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	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 A satellite of mass 80 kg is put into an orbit with an angular velocity equal to that at which the Earth rotates about its axis.

(a) Determine the angular velocity of the satellite.

angular velocity = ……. rad s^{-1} [2]

(b) Given the mass of Earth is 6.0×10^{24} kg, determine the radius of the orbit of the satellite.

radius = ……. m [2]

(c) Assuming that this satellite experiences friction in the outer space, describe the subsequent motion of the satellite.

……

…… [2]

(d) It is generally possible to have a satellite orbit the Earth from east to west as well as from west to east. Explain why it is normally preferred to launch a satellite from west to east at the equator.

…….....……

…….....……

…….....……

…….....……

…….....……..…… [3]

(e) Satellites orbiting with different orbital radii have different amount of gravitational potential energy, kinetic energy and total energy.

(i) Sketch on Fig. 1.1 the variation with orbital radius of the gravitational potential energy of orbiting satellites. Label the graph **GPE**. [2]

(ii) Sketch on Fig. 1.1 the variation with orbital radius of the total energy of orbiting satellites. Label the graph **TE**. [1]

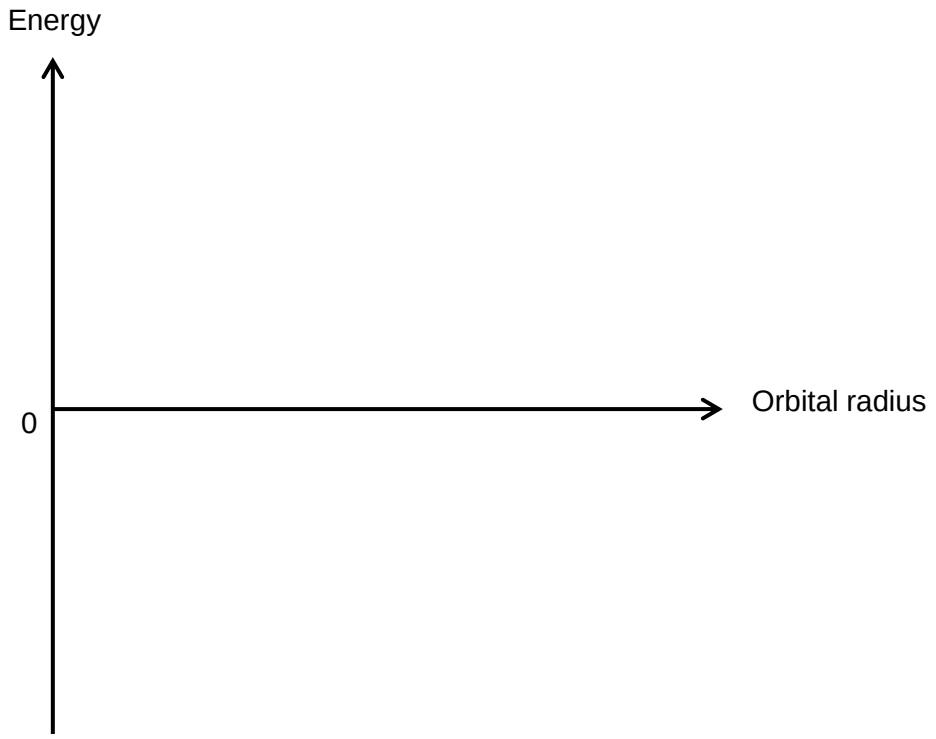

Fig. 1.1

2 (a) A common game in carnivals is the “high striker” whereby a player uses a hammer to hit a target pad at one end of a lever in order to launch a puck at the other end. The player wins if the puck hits the bell at the top of a tower. This is illustrated in Fig. 2.1.

In one such carnival, the hammer and puck weigh 9.00 kg and 0.40 kg respectively. The bell is located 5.00 m above the puck.

A student plays the game and just manages to ring the bell.

(i) Determine the gain in gravitational potential energy of the puck.

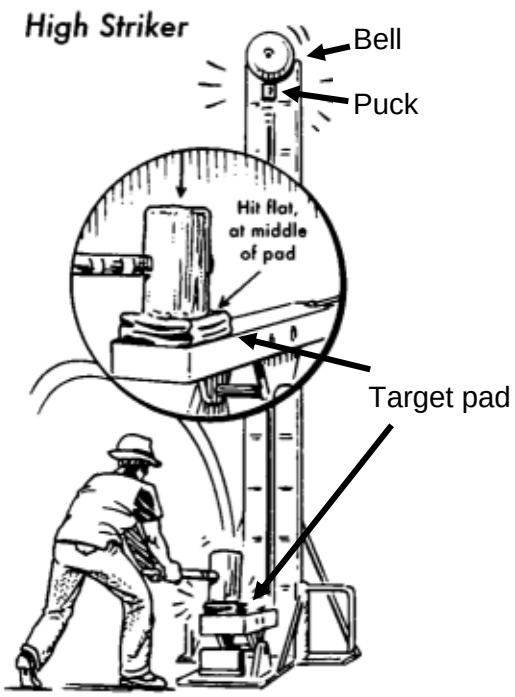

Fig. 2.1

gain in gravitational potential energy = …… J [1]

(ii) Suppose that 75% of the final kinetic energy of the hammer is transformed into thermal and sound energy, calculate the speed of impact of the student’s hammer on the lever.

speed of impact = …….. m s^{-1} [3]

(b) When a circuit is connected using an e.m.f. cell and an external resistor, the following equation is used:

$$V = E - Ir$$

. whereby E is the e.m.f. of the cell, r is the internal resistance and I is the current in the circuit.

(i) State what V represents.

.....[1]

(ii) An ideal voltmeter connected across the terminals of a cell reads 1.61 V. The reading drops to 1.34 V when a 3.0 Ω resistor is connected in parallel with the voltmeter as shown in Fig. 2.1.

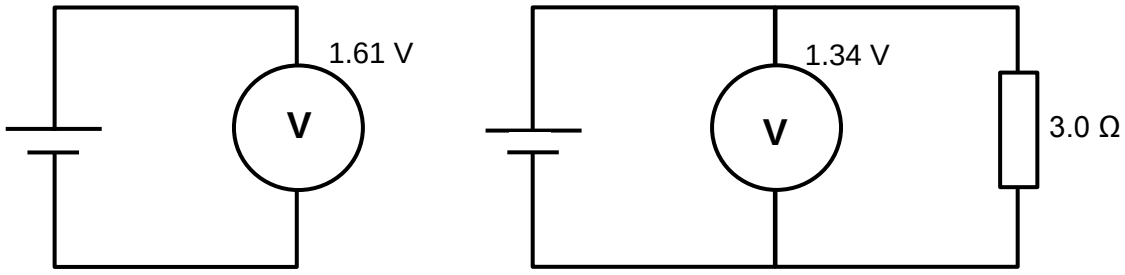

Fig. 2.1

1. Calculate the internal resistance of the cell.

internal resistance = ……. Ω [3]

2. A second resistor is connected in parallel with the 3.0 Ω resistor. Without doing any calculations, state and explain how V changes.

……

……

…… [2]

3 Fig. 3.1 shows a p-type semiconductor placed in contact with another of n-type semiconductor, forming a p-n junction.

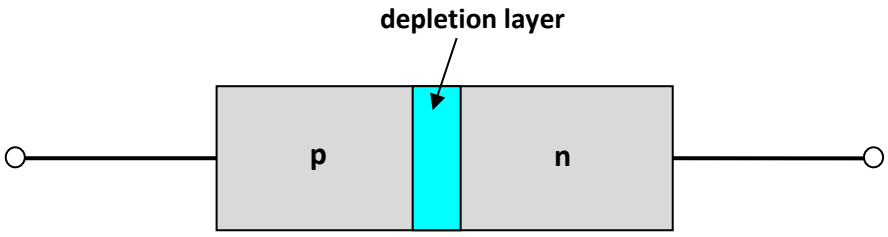

Fig. 3.1

(a) Explain what is meant by a *depletion region* in the p-n junction.

.....

..... [1]

(b) Explain how the depletion region is formed between the p-type and n-type semiconductors.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

(c) The p-n junction (diode) is used as a rectifier in a circuit consisting of a 50 Hz, 240 V alternating sinusoidal voltage source as shown in Fig. 3.2.

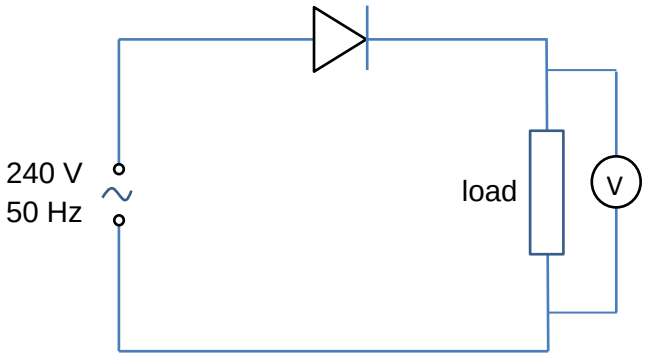

Fig. 3.2

(i) Sketch fully labelled graph to show variation with time t of the voltage V across the load in Fig. 3.3. [2]



Fig. 3.3

(ii) Calculate the V_{rms} of the voltage across the load.

V_{rms} = ... V [2]

4(a) Einstein's photoelectric equation appears in several forms, one of which is shown below:

$$E_{k\,\max} = h f - \phi$$

Monochromatic light of frequency 7.40×10^{14} Hz is irradiated onto a caesium surface, and $E_{k\,\max}$ is measured. The procedure is repeated for three other frequencies, enabling four points to be plotted on the graph grid of Fig. 4.1 below.

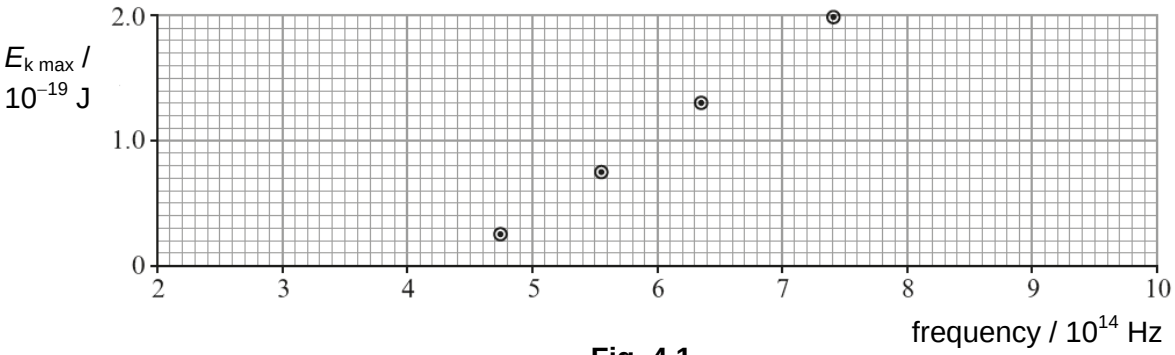

Fig. 4.1

(i) By showing your working, determine from Fig. 4.1,

1. a value for the Planck constant,

Planck constant = …….. J s [2]

2. the threshold frequency of caesium.

threshold frequency = …… Hz [1]

(ii) When another metal surface is used instead of a caesium surface, $E_{k\,\max}$ is found to be 0.40×10^{-19} J for light of frequency 8.50×10^{14} Hz.

1. Draw the expected line of $E_{k\,\max}$ against frequency on the same grid in Fig. 4.1. [1]

2. Explain why visible light cannot be used to verify the expected line drawn in **(ii) 1.** experimentally and state the region of the electromagnetic spectrum required.

……

……

……..…[2]

(b) Fig. 4.2 below illustrates how the potential energy E_p of an α-particle varies with distance r, measured along a line from the centre of a parent nucleus. R_o is the radius of the nucleus.

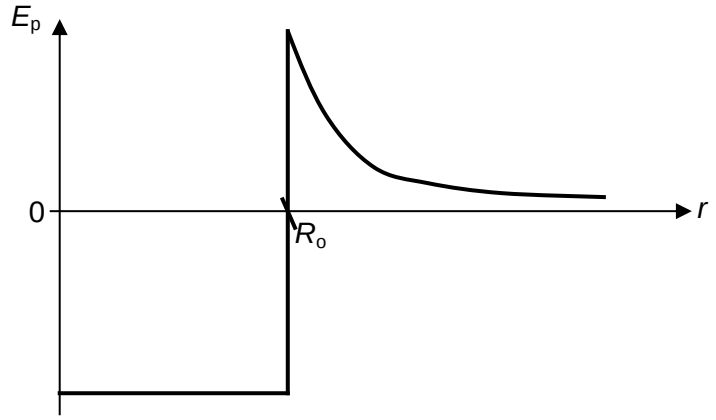

Fig. 4.2

Using this graph, suggest and explain how the energy of α-particles emitted is related to the length of the half-life of the parent nucleus.

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..... [4]

Section B

Answer **two** questions from this Section in the spaces provided.

5 (a) A tritium nucleus moves towards a deuterium nucleus at a large distance from deuterium nucleus as illustrated in Fig. 5.1.



Fig. 5.1

The nuclei initially have the same speed v. The tritium nucleus consists of two neutrons and a proton. The deuterium nucleus consists of a neutron and a proton. The proton and neutron are assumed to have the same mass m.

(i) Fig. 5.2 shows the electric force exerted by tritium nucleus on deuterium nucleus during the interaction. Draw the electric force exerted by deuterium nucleus on tritium nucleus in Fig. 5.2. [1]

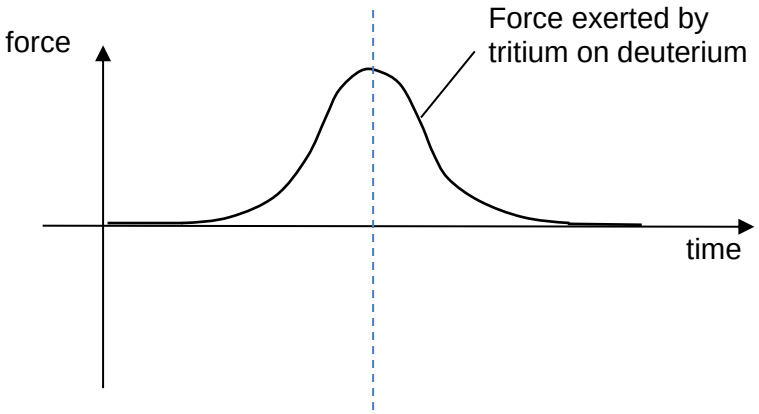

Fig. 5.2

(ii) Explain your answer to **(i)**.

……..

……..

……

…… [1]

(iii) Explain how your answer to **(i)** is consistent with the principle of conservation of momentum.

.....

……..

……..

……..

……..

…… [3]

(iv) Determine the final speed of tritium nucleus in terms of *v*.

final speed = …… [3]

(b) **(i)** Define *electric field strength*.

……...

……..

……. [1]

(ii) Fig 5.3 shows a charge +*q* at X in a uniform electric field of strength *E*.

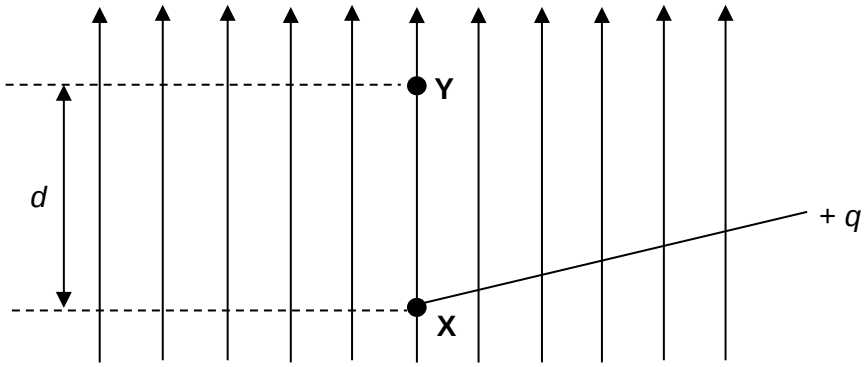

Fig. 5.3

The charge at X is moved to Y through a distance *d*. Use your definition in **(i)** to deduce an expression for the work done by external force.

expression for work done by external force = …… [1]

(iii) The potential difference between X and Y is *V*. Using your answer from **(ii)**, deduce an expression for the magnitude of *E* in terms of *V* and *d*.

expression for *E* = …….. [1]

(c) A stream of nuclear particles, travelling horizontally at 4.5×10^6 m s^{-1}, is deflected as it passes through a vacuum between two parallel plates as shown in Fig. 5.4.

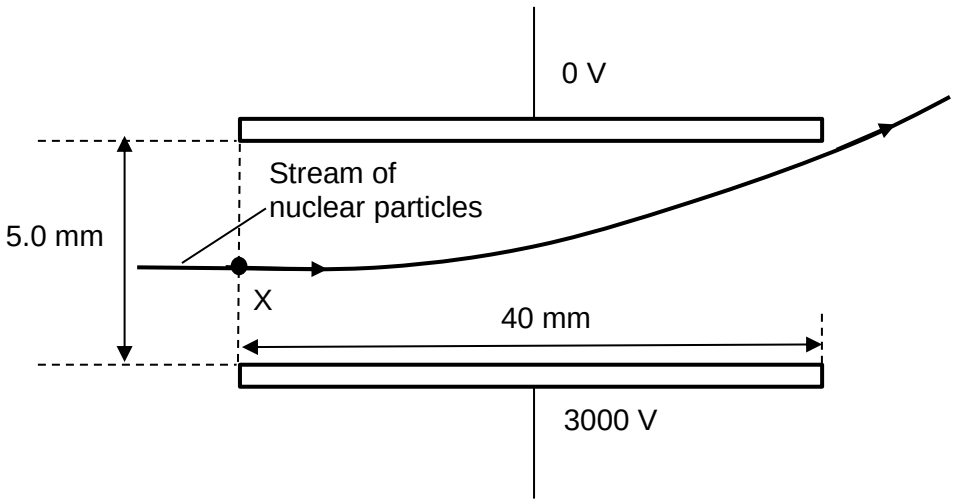

Fig. 5.4 (not to scale)

The separation of the plates is 5.0 mm, their length is 40 mm and the potential difference across the plates is 3000 V. The vertical displacement of the particles against the horizontal displacement is shown in Fig. 5.5. The horizontal displacement is measured from point X when it just entered the plate.

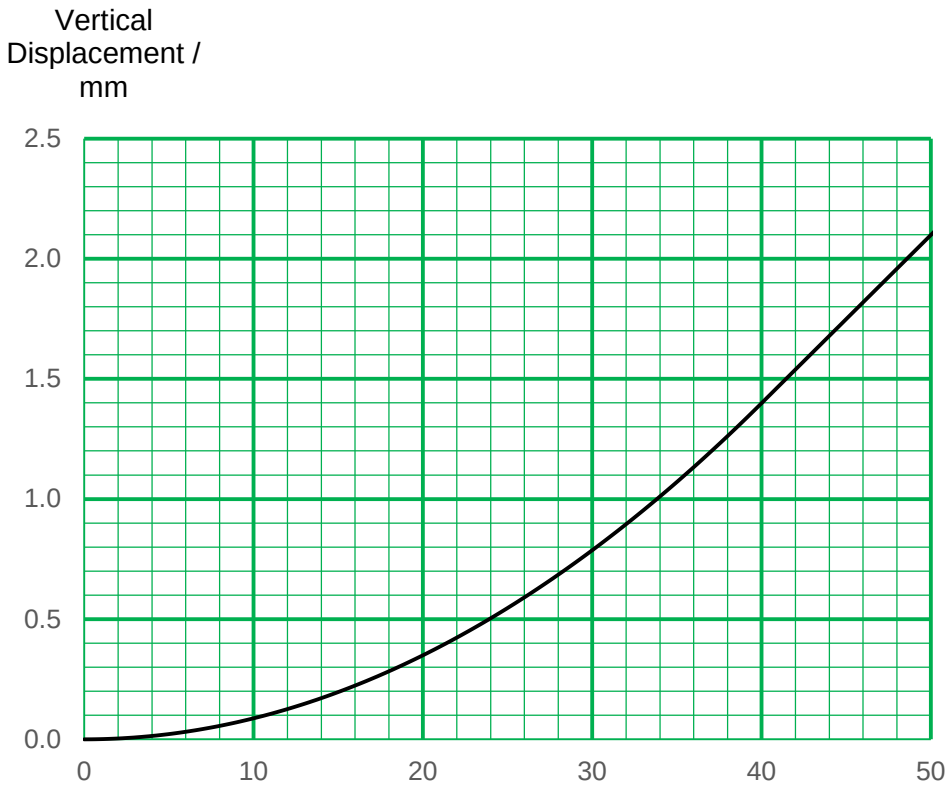

Fig. 5.5

(i) Calculate the time for which the particle is between the plates.

time = …… s [1]

(ii) Determine the vertical acceleration from graph shown in Fig. 5.5.

vertical acceleration = …….. m s^{-2} [2]

(iii) Calculate the electric field strength between the plates.

electric field strength = …… V m^{-1} [2]

(iv) Each nuclear particle carries a positive charge of 3.2×10^{-19} C. Using the value in **(ii)** and **(iii)**, calculate the mass of each particle.

mass of particle = …….. kg [2]

(v) State and explain what would happen to the deflection of the nuclear particles if the separation between the plates decreases.

.....

.....

.....

…….. [2]

6(a) Explain what is meant by the following terms in italics.

(i) *coherent* sources

……

……[1]

(ii) *phase difference*

……

……[1]

(iii) *diffraction*

……

……[1]

(b) **(i)** State the conditions for a well-defined stationary wave to be formed using two separate sound sources.

……

……

……[2]

(ii) Compare the amplitude, phase and frequency of motion of particles between a stationary and progressive wave.

……

……

……

……

……

……

……

……

……

……

……[5]

(c) In Fig. 6.1, a straight road runs parallel to the line joining two radio transmitting aerials A and B which are 600 m apart. Both aerials radiate signals at a frequency of 50 MHz. The road is 4.8 km from the aerials at its nearest point X.

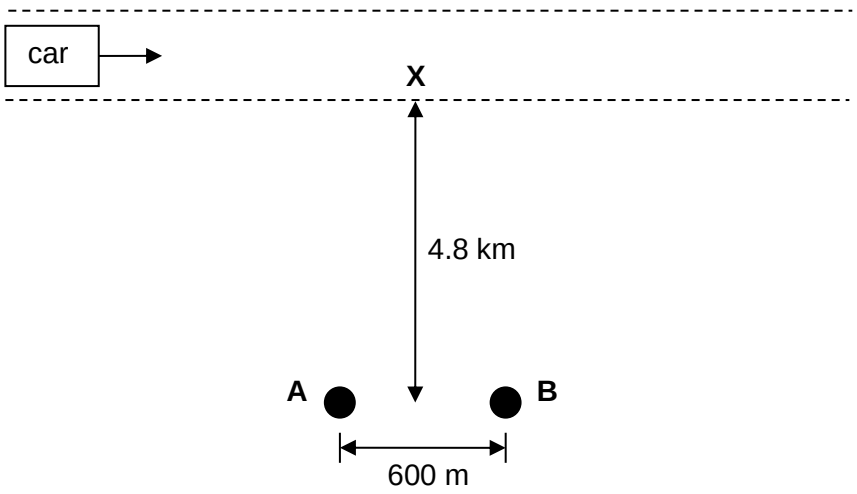

Fig. 6.1

A car travels at a steady speed along the road. As it passes along the road, it receives a radio signal which varies its intensity periodically.

(i) Explain why the intensity of the radio signal received varies as described.

……

……

……

……

……[3]

(ii) It is found that the maximum intensity of the radio signal is received at a frequency of 0.50 Hz. Calculate the speed of the car.

speed of car = ……..... m s^{-1} [3]

(d) In Fig. 6.2, S_1 and S_2 are two coherent point sources placed at a distance d apart.

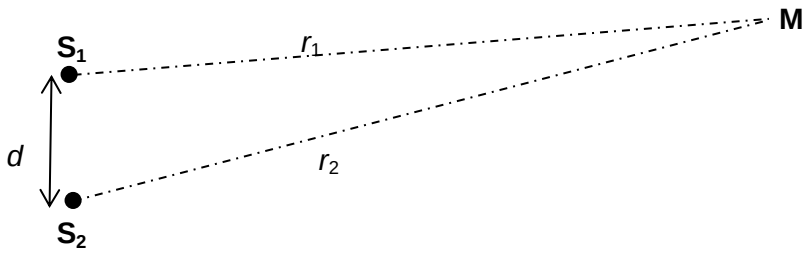

Fig. 6.2

The sources emit waves that are in phase. Each wave has an amplitude A and wavelength λ. The distances of M from S_1 and S_2 are r_1 and r_2 respectively.

(i) Deduce the ratios of the intensities and the amplitudes, in terms of r_1 and r_2, of the waves from S_1 and S_2 when they arrive at M. [3]

ratio of intensities = ……..

ratio of amplitudes = ……..

(ii) Hence or otherwise, explain why there is no complete cancellation of the two waves at M although the waves arrive at M anti-phase to each other.

…….....

……..... [1]

7 (a) A doubly-charged positive ion of the copper isotope Cu is projected into a vertical magnetic field of flux density 0.28 T as shown in Fig. 7.1. The magnetic field is directed upwards. The ion enters the field at a speed of 7.8×10^5 m s^{-1}.

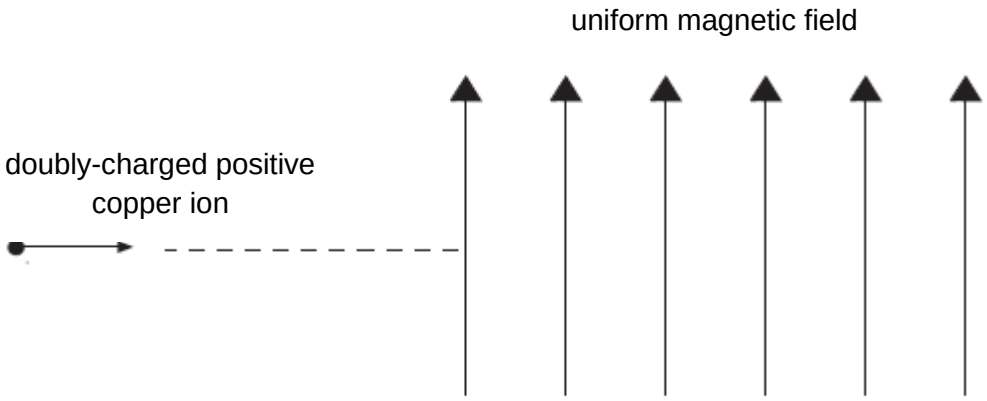

Fig. 7.1

(i) State the initial direction of the magnetic force that acts on the ion.

..... [1]

(ii) Describe the subsequent path of the ion as fully as you can. Your answer should include both a qualitative description and a calculation.

mass of $^{63}_{29}$Cu ion = 1.05×10^{-25} kg

Calculation:

.....

.....

..... [3]

(iii) State the effect on the path in part **(ii)** if the following changes are made separately.

1. The strength of the magnetic field is doubled.

.....

..... [1]

2. A singly-charged positive Cu ion replaces the original one.

.....

..... [1]

(b) The table in Fig. 7.2 gives the values for the activity of a radioactive isotope over a period of a few minutes.

Time / s	0	60	120	180	240	300
Activity / Bq	480	366	280	214	163	124

Fig. 7.2

(i) Complete the graph in Fig. 7.3 by plotting the remaining points and drawing an appropriate curve. [3]

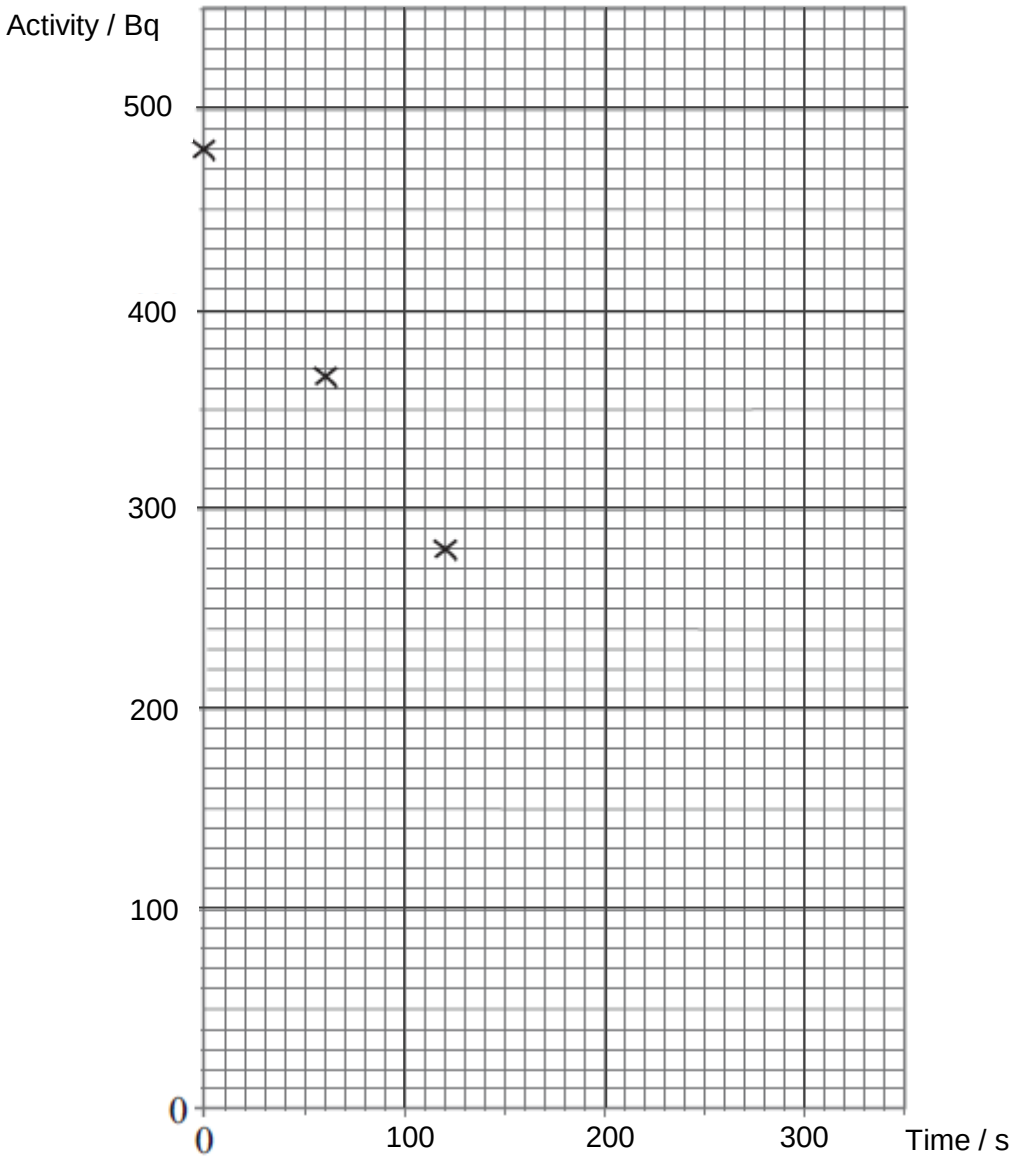

Fig. 7.3

(ii) **Use the graph** in Fig. 7.3 to determine the half-life of the isotope. Show and explain your steps clearly.

half-life = ... s [2]

(iii) Initially there were 1.1×10^5 atoms of the isotope present. Calculate the decay probability of the isotope.

decay probability = ... s^{-1} [2]

(c) **(i)** Explain what is meant by binding energy.

.....

.....

..... [1]

(ii) Given that

rest mass of $^{226}_{90}$Th = 226.0249 u

rest mass of proton = 1.0073 u

rest mass of neutron = 1.0087 u

calculate the binding energy of a thorium nucleus $^{226}_{90}$Th.

binding energy = ... Mev [3]

(iii) A thorium nucleus $^{226}_{90}$Th originally at rest decays and forms a radium nucleus $^{222}_{88}$Ra* and an alpha particle as shown below. The radium nucleus $^{222}_{88}$Ra* is in an excited state.

$$^{226}_{90}\text{Th} \rightarrow {}^{222}_{88}\text{Ra}^* + {}^{4}_{2}\text{He}$$

Given that

rest mass of $^{226}_{90}$Th = 226.0249 u

rest mass of $^{222}_{88}$Ra = 222.0154 u

rest mass of $^{4}_{2}$He = 4.0026 u

determine the kinetic energy of the radium nucleus if the alpha particle is emitted with a kinetic energy of 2.38 MeV. Explain your working and state an assumption made in your calculations.

kinetic energy = ... J [2]

Assumption : .....

…….....[1]

- End of Paper -

Candidate's Name …… CTG ……

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2016

PHYSICS **9646/1**
HIGHER 2 **26 August 2016**
Paper 1 Multiple Choice **Friday**
1 hour 15 minutes

Additional Materials:
Optical Mark Sheet

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READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

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

Write your name and CTG on the Optical Mark Sheet in the spaces provided.
Shade your NRIC in the space provided.

There are **forty** 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 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.

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}
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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	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	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
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	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 A boat changes its velocity from 16 m s^{-1} due north to 12 m s^{-1} due east.

What is its change in velocity?

A 4 m s^{-1} at direction of 37° east of north

B 4 m s^{-1} at direction of 53° west of north

C 20 m s^{-1} at direction of 37° east of south

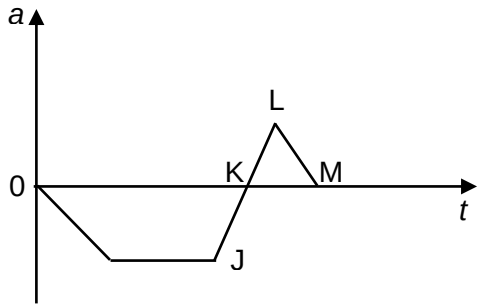
D 20 m s^{-1} at direction of 53° west of south

2 A student uses an analogue mass balance to measure mass. The mass balance is marked for every 0.2 kg but has a zero error of 0.4 kg. The student is not aware of this zero error and writes down a reading of 2.2 kg.

Is this reading accurate and precise?

	accurate	precise
A	no	no
B	no	yes
C	yes	no
D	yes	yes

3 A car starts from rest and travels along a straight road. The graph shows the variation with time *t* of its acceleration *a*, during part of the journey.



At which points on the graph does the car have its greatest speed and greatest displacement?

	greatest speed	greatest displacement
A	J	K
B	K	M
C	L	L
D	M	K

4 A motorist travelling at 13 m s^{-1} approaches a traffic light which turns red when he is 25 m away from the stop line. His reaction time (i.e. the interval between seeing the red line and applying the brakes) is 0.70 s and he brakes at a rate of 4.5 m s^{-2}. How far from the stop line will he stop, and on which side of it?

A 2.9 m behind the line

B 2.9 m beyond the line

C 4.0 m behind the line

D 4.0 m beyond the line

5 Newton's third law of motion concerns action and reaction forces.

Which pair of forces is not a valid example?

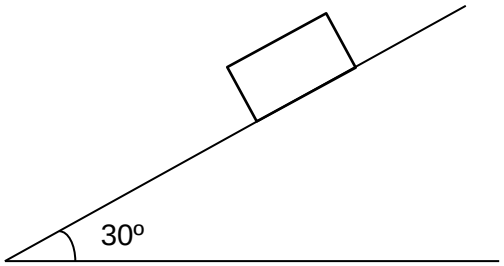
A The gravitation forces of attraction between the Earth and the satellite orbiting around the Earth

B The forces of repulsion between the horse magnet and a wire carrying current placed in between the horse magnet

C Upthrust on the block immersed in water and the force exerted by the block on water

D Weight of the book and the normal force from the floor on the book which is placed on the floor

6 A 1.0 kg block is placed on the slope which is inclined at angle of 30º as shown in the figure.

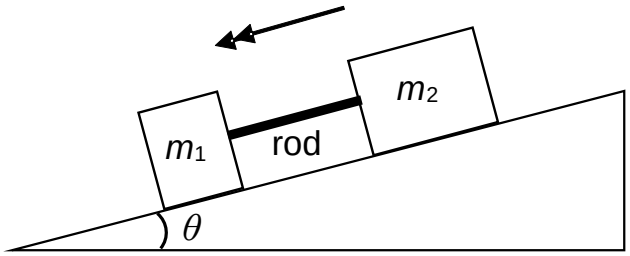


Assuming that the frictional force acting on the block is 2.5 N, what is the downward acceleration along the slope after the block is released from rest?

A 2.41 m s^{-2} **B** 4.91 m s^{-2} **C** 6.00 m s^{-2} **D** 9.81 m s^{-2}

7 Two masses m_1 and m_2 are connected by a light rod as shown.

The blocks are moving with acceleration *a,* down a smooth slope that is inclined at angle θ. What is the tension in the rod?

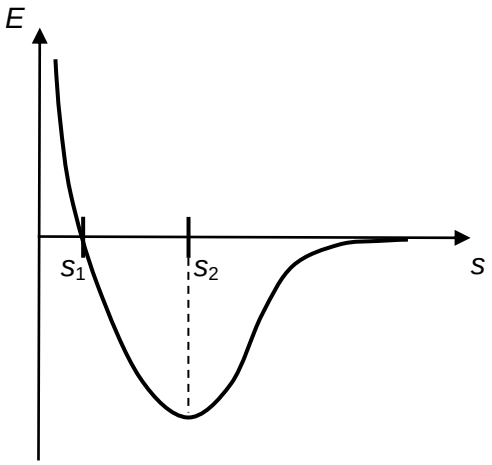


A $m_1 a$ (sin θ) **B** $(m_1 - m_2)a$ **C** $(m_1 + m_2)a$ **D** zero

8 A man sitting in a train carriage observes that a pendulum hanging from the ceiling makes an angle of 30º to the vertical. What is the acceleration of the train?

A 4.9 m s^{-2} **B** 5.7 m s^{-2} **C** 8.5 m s^{-2} **D** 9.8 m s^{-2}

9 The mutual potential energy E of two molecules separated by a distance s is shown in the graph below.



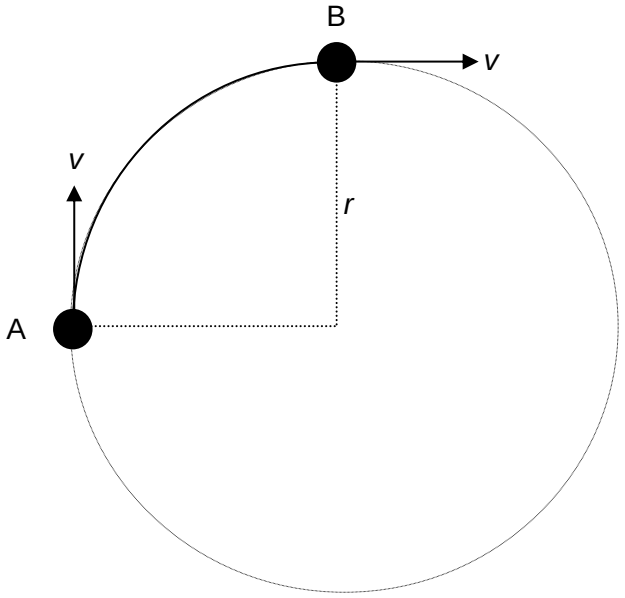
Which of the following correctly describes the forces between the molecules?

	attractive for	repulsive for
A	$s < s_2$	$s > s_2$
B	$s > s_2$	$s < s_2$
C	$s < s_1$	$s > s_1$
D	$s > s_1$	$s < s_1$

10 The power delivered by an engine to a train travelling at a constant speed of 45 m s^{-1} is 2.0 MW. What is the resistive force it experiences?

A 0 N **B** 9.9×10^2 N **C** 2.2×10^4 N **D** 4.4×10^4 N

11 A ball of mass *m* attached to a rope is swung in a horizontal circle of radius *r*. What is the work done on the ball by the tension in the rope as it moves from A to B?



Top view

A zero

B $m\,g\,r$

C $m\,v^2$

D $\frac{1}{2}\pi m\,v^2$

12 A small ball is moving in a vertical circle at constant speed. The magnitude of the resultant force acting on the ball

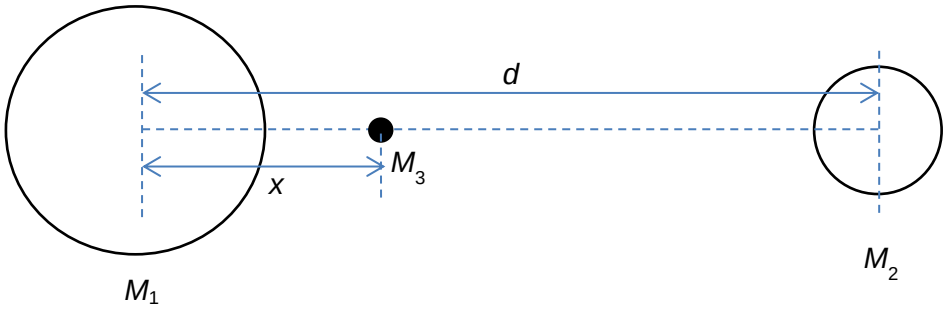
A is largest at the bottom of the circle and smallest at the top of the circle.

B is smallest at the bottom of the circle and largest at the top of the circle.

C is the same at the top and bottom of the circle.

D is zero at the top of the circle.

13 Two planets of masses M_1 and M_2 are a distance d apart. A third planet M_3 is found at a distance x from M_1. Which of the following correctly shows the expressions to determine the resultant gravitational force and gravitational potential energy of M_3?



	resultant gravitational force	gravitational potential energy
A	$\frac{GM_1M_3}{x^2} - \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} - \frac{GM_2M_3}{(d-x)}$
B	$\frac{GM_1M_3}{x^2} + \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$
C	$\frac{GM_1M_3}{x^2} - \frac{GM_2M_3}{(d-x)^2}$	$-\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$
D	$\frac{GM_1M_3}{x^2} + \frac{GM_2M_3}{(d-x)^2}$	$\frac{GM_1M_3}{x} + \frac{GM_2M_3}{(d-x)}$

14 A spacecraft has been launched from surface of Planet X into space. When it is at a distance from the planet, the engine is shut down and the spacecraft continues its motion away from the planet. Ignoring the influence of all other celestial bodies, which of the following is **true**?

A The gravitational potential energy of the spacecraft is decreasing.

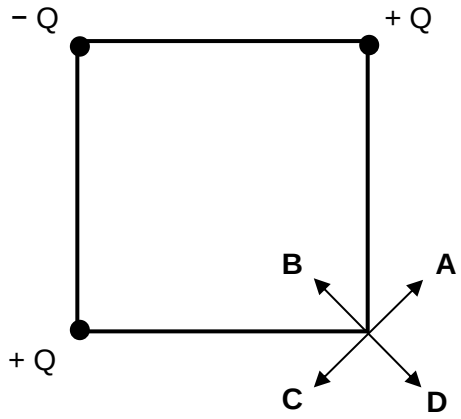
B The spacecraft continues to move with constant velocity.

C The gravitational force experienced by the objects in the spacecraft is zero.

D The gravitational force experienced by the objects in the spacecraft is decreasing in value.

15 The diagram shows three point charges, each of magnitude Q, placed at three corners of a square.

What is the direction of the resultant electric field at the fourth corner?



16 The electric potential of an isolated point charge has magnitude V at a distance of 2.0 m away from the point charge. What is the distance from the charge when the magnitude of electric potential is $\frac{V}{4}$?

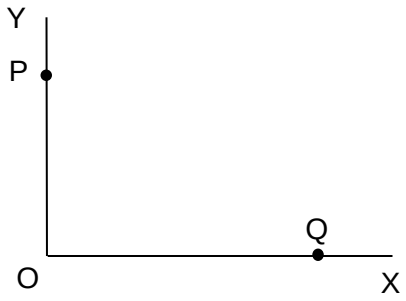
A 4.0 m

B 8.0 m

C 12.0 m

D 16.0 m

17 The diagram shows a flat surface with lines OX and OY at right angles to each other.



A straight current carrying conductor is placed at a position such that the magnetic field at O is found to be in the direction OX.

Which of the following correctly shows the position of the straight conductor and the direction of its current flow?

	position	direction of current flow
A	P	into the plane
B	P	out of the plane
C	Q	into the plane
D	Q	out of the plane

18 An electron is moving along the axis of a current-carrying solenoid.

Which of the following is a correct statement about the electromagnetic force acting on the electron?

A The electromagnetic force acts radially outwards.

B The electromagnetic force acts radially inwards.

C The electromagnetic force acts in the direction of motion.

D No electromagnetic force acts on the electron.

19 A resistor of resistance *R* has power *P* when the current in the resistor is I. What is the resistance of a resistor that has power 2*P* when the current in the resistor is $\frac{I}{2}$?

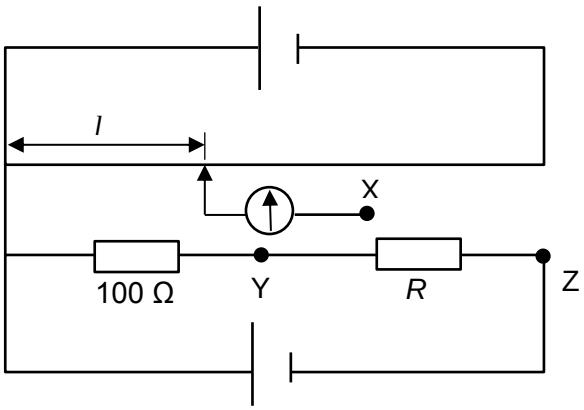
A $\frac{R}{8}$

B $\frac{R}{4}$

C $4R$

D $8R$

20 A circuit which may be used to compare the resistance *R* of an unknown resistor with 100 Ω standard is shown. When X is connected to Y, the distance l from the left end of potentiometer slide wire to the balance point is 400 mm. When X is connected to Z, the distance l from left end of potentiometer slide wire to the balance point is 600 mm.



Which of the following is the value of resistance *R*?

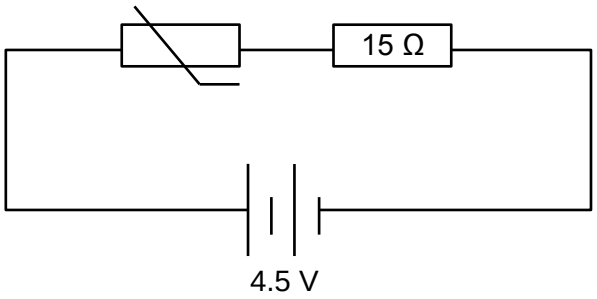
A 50 Ω

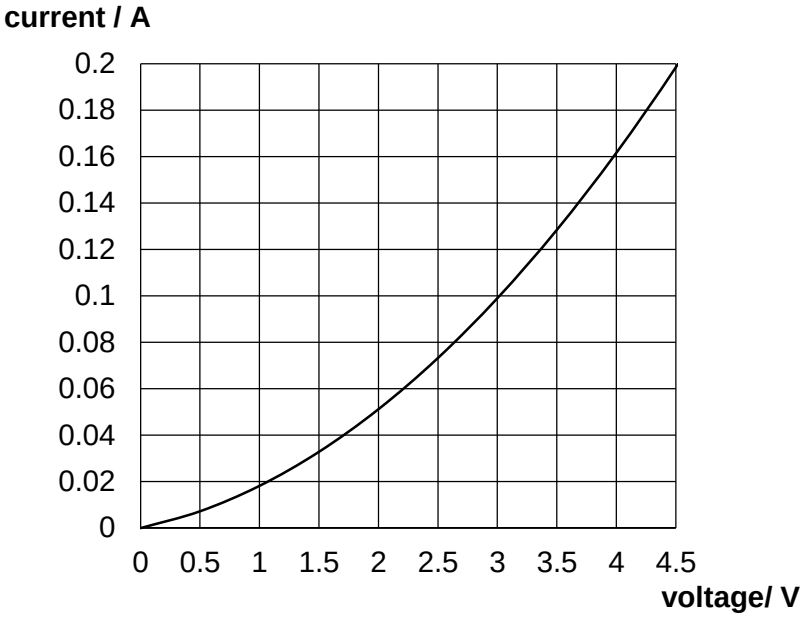
B 100 Ω

C 150 Ω

D 200 Ω

21 A 15 Ω resistor and a thermistor are connected in series to a battery of electromotive force 4.5 V and negligible internal resistance.





The graph above shows the current – voltage characteristic of the thermistor.
What is the current in the circuit?

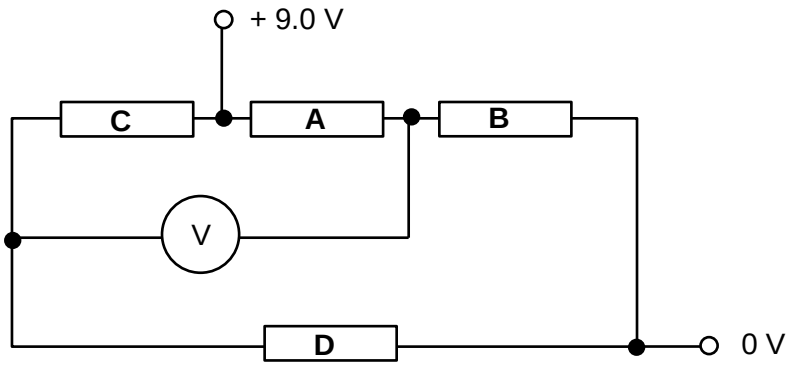
A 0.05 A

B 0.10 A

C 0.15 A

D 0.20 A

22 In the circuit below, the resistance of resistors **A** and **D** is R while the resistance of resistors **C** and **B** is $2R$.



The potential difference between the input terminals is 9.0 V.
What is the reading on the voltmeter?

A 0 V **B** 3.0 V **C** 6.0 V **D** 9.0 V

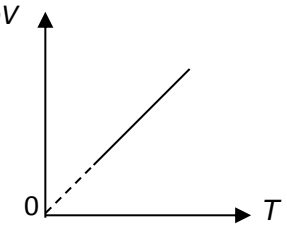
23 Container X contains neon and container Y contains argon. The two containers are identical and the two gases are at the same temperature. The pressure in X is twice that in Y. What is the ratio of the mean kinetic energy of a neon atom to the mean kinetic energy of an argon atom?

[The relative atomic masses of neon and argon are 20 and 40 respectively.]

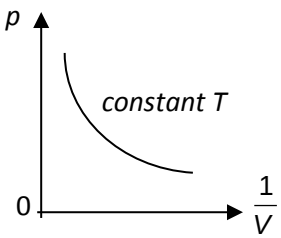
A 0.5 **B** 1 **C** 2 **D** 4

24 Which of the following graphs correctly describes the behaviour of a fixed mass of an ideal gas at pressure p, volume V and thermodynamic temperature T ?

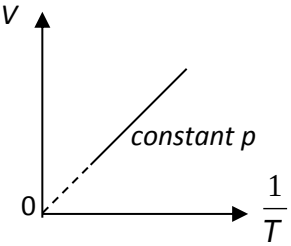
A



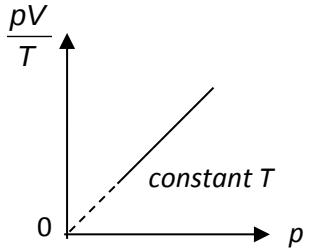
B



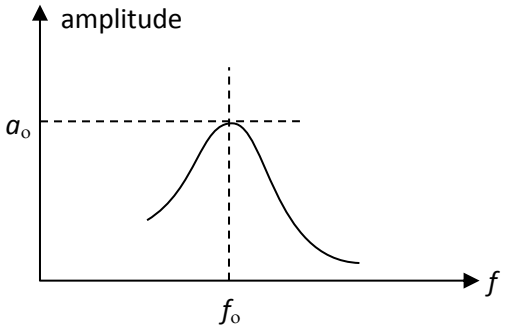
C



D

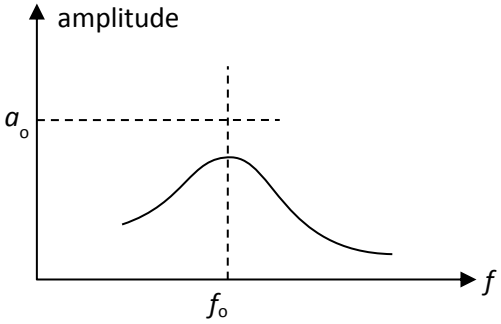


25 A pendulum is constructed from a fixed length of light thread and a spherical, polystyrene bob. It is forced to oscillate in oil at different frequencies *f*. The following diagram shows how the amplitude of its oscillation varies with *f*.

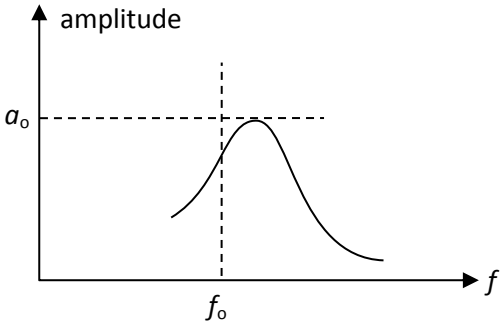


The experiment is repeated in air. Which graph best represents the variation with *f* of the amplitude?

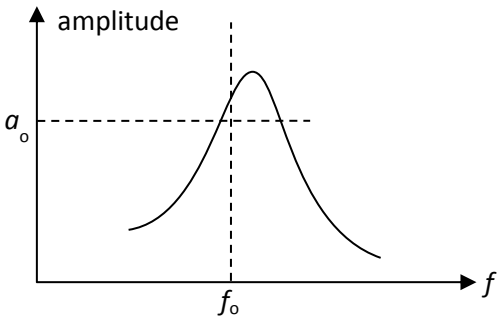
A



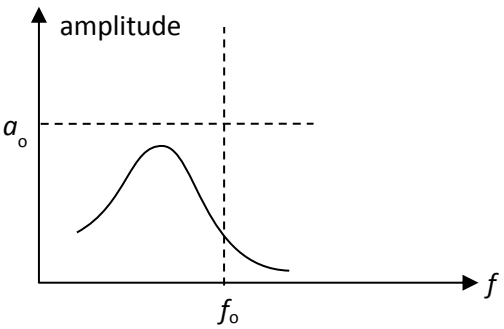
B



C



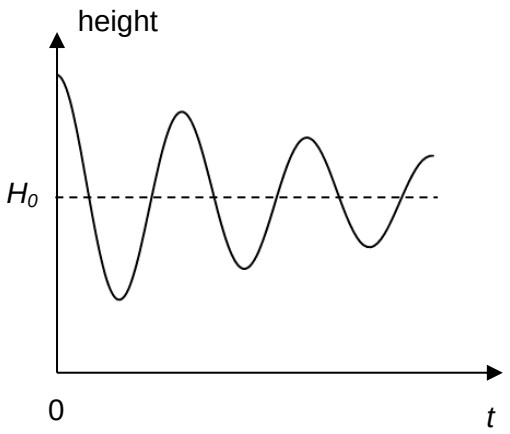
D



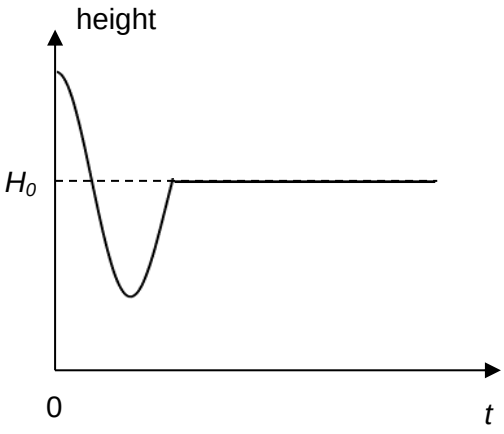
26 The equilibrium height of a car body above the ground is H_0. At time t = 0, the car body is raised slightly to a greater height and released. The tyres of the car may be assumed to remain in contact with the ground throughout and its suspension may be taken to be overdamped.

Which of the following correctly represents the variation of the height of the car body with time?

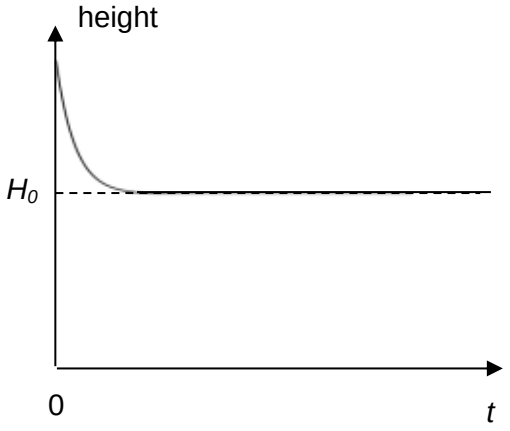
A



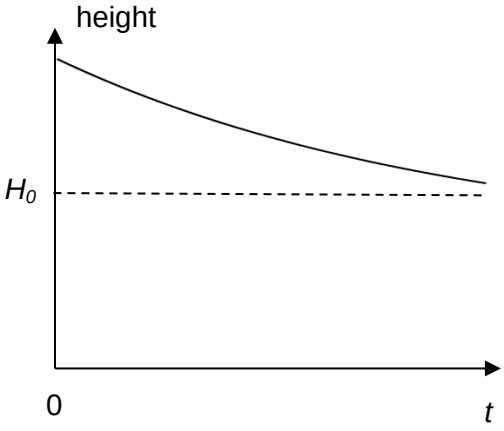
B



C



D



27 Which of the following statements is incorrect about progressive mechanical waves?

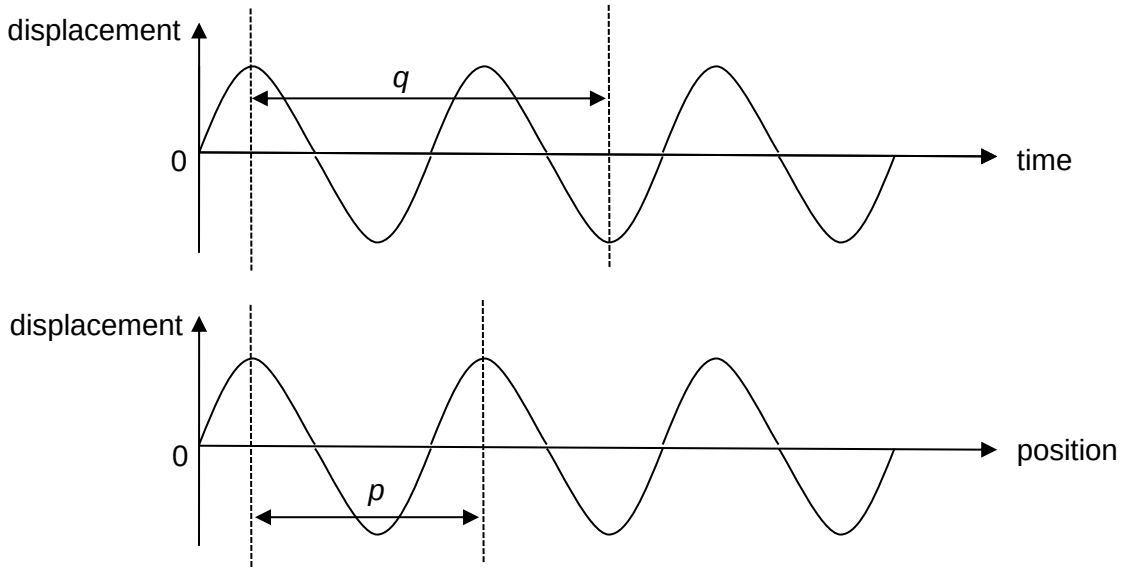
A They propagate due to interaction between the particles of the medium.

B They can be transverse or longitudinal.

C They carry energy as they propagate.

D They can always be polarized.

28 A progressive wave can be represented by the following two graphs.



Which of the following gives the speed of the wave?

A $\frac{q}{p}$ **B** $\frac{p}{q}$ **C** $\frac{2p}{3q}$ **D** $\frac{3p}{2q}$

29 Light of wavelength λ is incident normally on a diffraction grating with slit separation 5λ. What is the angle between the second order maximum and third order maximum?

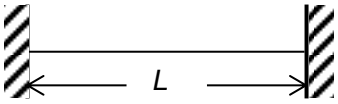
A 11.5°

B 13.3°

C 23.6°

D 36.9°

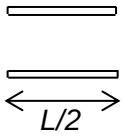
30 The figure below shows a stretched string of length *L*. The speed of waves on the string has the same speed as sound waves in the air. The fundamental mode of oscillation is then set up on the string.



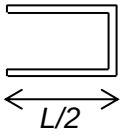
Pipes **A**, **B**, **C** and **D** below have lengths of *L/2*, *L/2, L* and *2L* respectively.

In which pipe will the sound produced by the string cause resonance?

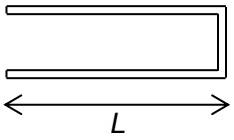
A



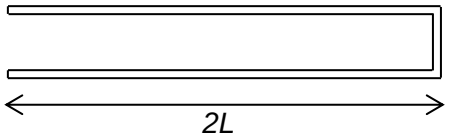
B



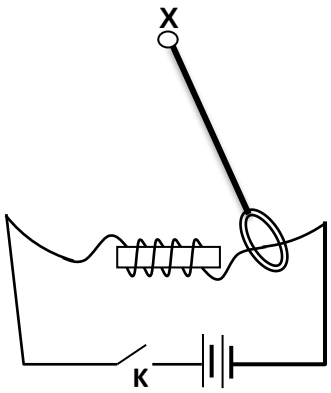
C



D



31 A copper ring is suspended by a long, light rod pivoted at X so that it may swing as a pendulum, as shown. An electromagnet is mounted so that the ring passes over it as it swings.



Switch K is initially open when the ring is set into oscillation. What happens to the motion after switch K is closed?

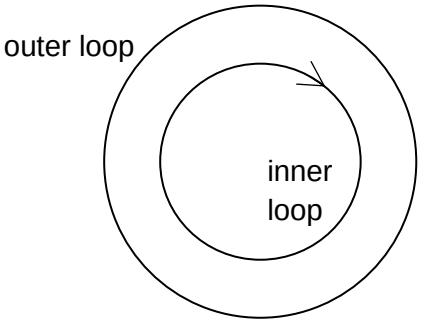
A The periodic time will decrease.

B The oscillation will be heavily damped.

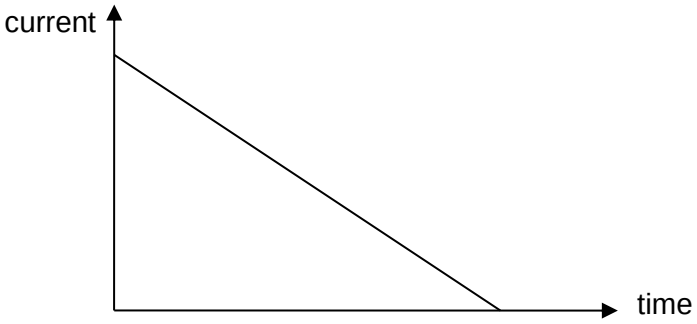
C The amplitude will increase because the ring is repelled by the electromagnet and hence it swings further away.

D The oscillation will continue at constant amplitude since the battery can supply energy to sustain the oscillation.

32 The diagram below shows two concentric loops in the same plane.



The current in the inner loop is flowing clockwise. The variation of the magnitude of the current with time is shown below.



The induced current in the outer loop is

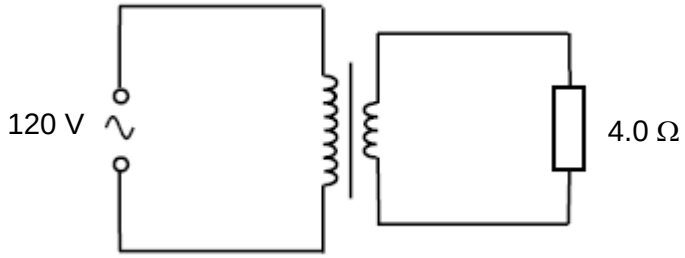
A increasing in the anticlockwise direction.

B constant in the anticlockwise direction and eventually decreases to zero.

C constant in the clockwise direction and eventually decreases to zero.

D decreasing in the clockwise direction.

33 An ideal transformer is used to step down a 120 V a.c. voltage supply. The ratio of secondary turns to the primary turns is 1:20.



What is the current in the primary coil?

A 30 A **B** 6.0 A **C** 1.5 A **D** 0.075 A

34 Electrons in a beam undergo diffraction when incident on a crystalline solid. Given that the order of magnitude of the separation of atoms in the solid is 0.1 nm, what is the estimated speed of an electron in the beam?

A 10^{-24} m s^{-1} **B** 10^{-10} m s^{-1} **C** 10^{5} m s^{-1} **D** 10^{6} m s^{-1}

35 Which of the following observations in the photoelectric effect does not require the use of quantum theory of electromagnetic radiation to explain?

A The existence of a threshold frequency

B The dependence of stopping voltage with frequency of incident radiation

C The relationship between photocurrent and intensity of incident radiation

D The almost instantaneous emission of electrons once radiation of high enough frequency arrives

36 The transition of electrons between three consecutive energy levels in a particular atom gives rise to three spectral lines. The shortest and longest wavelengths of those spectral lines are λ_1 and λ_2 respectively. The wavelength of the other spectral line is

A $\frac{\lambda_1 + \lambda_2}{2}$

B $\lambda_1 - \lambda_2$

C $\frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$

D $(\frac{1}{\lambda_1} - \frac{1}{\lambda_2})^{-1}$

37 What is stimulated emission in LASER?

A An electron from a higher energy level falling to a lower level.

B A charged particle causing light to be emitted from an excited atom.

C A charged particle being emitted from an atom as a result of a high energy photon hitting the atom.

D A photon causing another photon of the same frequency to be emitted from an excited atom.

38 A p-type semiconductor is brought into contact with an n-type semiconductor to form a p-n junction. An application of a p-n junction is to rectify an alternating current. Which of the following statements is false?

A During forward bias condition of a p-n junction, if the applied p.d. overcomes the junction potential, electrons will cross steadily from the n-type side to the p-type side.

B During reverse bias condition of a p-n junction, the width of the depletion region becomes larger as the externally applied p.d. adds to the junction potential.

C During reverse bias condition of a p-n junction, the p-type semi-conductor becomes less negative.

D Under increasingly high reverse bias p.d., current can increase sharply through the p-n junction.

39 The fusion of two deuterium nuclei produces a nuclide of helium and a neutron. It liberates 3.27 MeV of energy.

How does the total mass of the two deuterium nuclei, $M_{reactants}$, compare with the total mass of the helium nucleus and neutron, $M_{products}$?

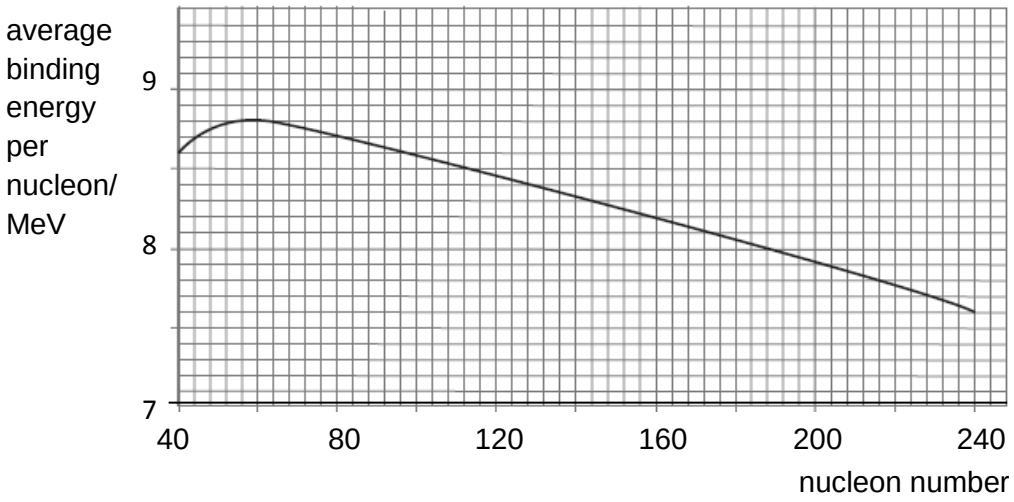
A $M_{reactants}$ is more than $M_{products}$ by 5.8×10^{-30} kg

B $M_{reactants}$ is less than $M_{products}$ by 5.8×10^{-30} kg

C $M_{reactants}$ is more than $M_{products}$ by 5.8×10^{-36} kg

D $M_{reactants}$ is less than $M_{products}$ by 5.8×10^{-36} kg

40 The figure below shows an enlarged portion of a graph indicating how the average binding energy per nucleon of various nuclides varies with their nucleon number.



During the fission of a uranium-236 nucleus, the nucleus splits into two roughly equal parts and

A approximately 200 MeV of energy is released.

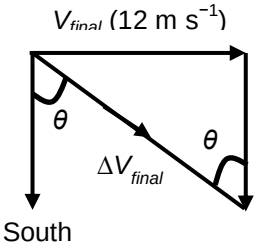
B approximately 1800 MeV of energy is released.

C approximately 200 MeV of energy is absorbed.

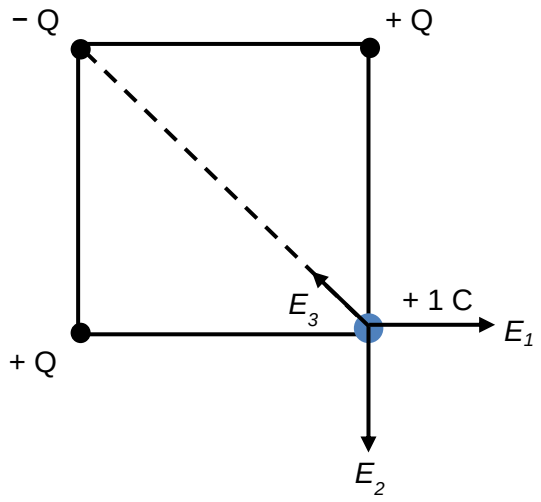
D approximately 1800 MeV of energy is absorbed.

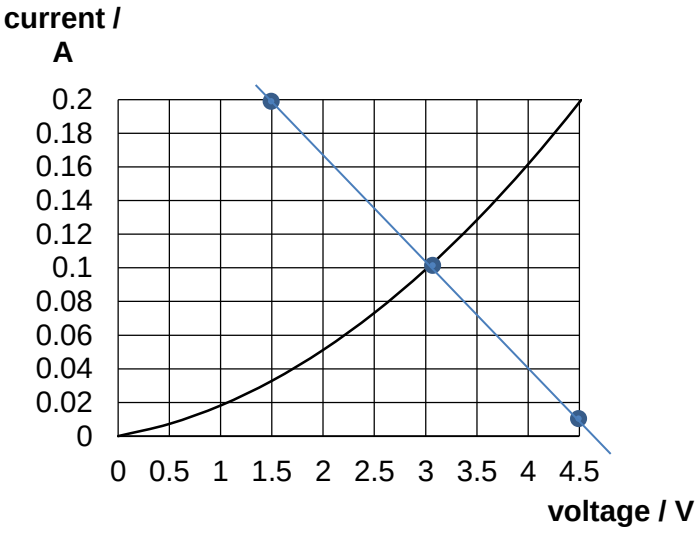
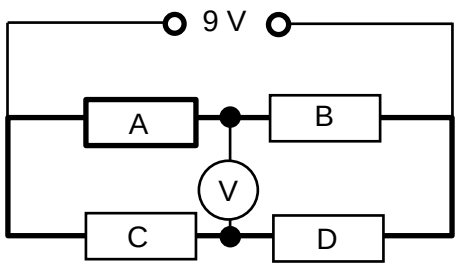
END OF PAPER

Paper 1 MCQs Solution:

S/N	Answer	Explanation
1	C	 $\Delta V_{final}^2 = 12^2 + 16^2$ $\Delta V_{final} = 20$ m s^{-1} tan θ = 12 /16 θ = 37°
2	B	The smallest division on the mass balance is 0.2 kg. Absolute uncertainty is 0.1 kg for one reading (half of smallest division) and 0.2 kg for two-readings measurement. The student has recorded his reading to the right precision. Hence, the reading is precise. However, it is not accurate as there is zero error which is unaccounted for.
3	B	Car accelerates (gain in speed) until point K. Since area under triangle between K and M is smaller than area under trapezium from 0 to K, the car maintains speed in the same direction throughout the motion. Therefore, car is gaining displacement until point M.
4	B	Distance traveled before brakes are applied = 13 x 0.7 = 9.1 m Using $v^2 = u^2 + 2as$, s = 18.8 m Total distance travelled = 9.1 + 18.8 = 27.9 m. Distance beyond the stop line = 27.9 – 25 = 2.9 m
5	D	The gravitation force of attraction between satellite and earth is a pair of action and reaction force. Wire with current flowing will generate magnetic field around it. Hence, the wire acts a magnet which interacts with the horse magnet. Hence the magnetic forces of repulsion is a pair of action and reaction force. The upthrust is a force exerted by the water on the block. Hence upthrust and force by the block on the water is a pair of action and reaction force. The normal force is exerted by the floor on the floor. Weight of the book is exerted by the earth on the book. These two forces are of different type of forces and hence they cannot be a pair of action and reaction force.
6	A	Net force down the slope = mg sin θ – Fr = 1 x 9.81 x sin 30° − 2.5 = 2.405 N Acceleration down the slope = 2.405 / 1.0 = 2.41 m s^{-2}
7	D	m_1 and m_2 have the same acceleration. Considering rod, m_1 and m_2 as a system, $(m_1 + m_2)g \sin \theta = (m_1 + m_2) a$ $a = g \sin \theta$ considering m_1 as a system, $m_1 g \sin \theta - T = m_1 a$, $m_1 a - T = m_1 a$, T = 0

8	**B**	Since object is in translational equilibrium, (leftwards forces = rightward forces) Mass of ball x Acceleration of ball = horizontal component of Tension in string. ma = T sin 30 – (1) (upward forces = downward forces) Weight of ball = vertical component of Tension in string. mg = T cos 30 – (2) (1)/(2): a/g = tan 30 a = g tan 30 = 5.7
9	**B**	Gradient of graph gives the negative of the force
10	**D**	$P_{eng} = F_{eng}\, v \Rightarrow F_{eng} = 2 \times 10^6 / 45 = 4.4 \times 10^4$ N Since velocity is constant, $F_{resist} = F_{eng}$
11	**A**	Zero. The tension is acting perpendicular to the displacement throughout the motion. Hence there is no work done by the tension.
12	**C**	The magnitude of the *resultant force* for a *uniform circular motion* is always the same at all position of the circle. The *tension* that causes the circular motion may however change and is smallest at the top and largest at the bottom of the circle.
13	**A**	Gravitational force is a vector quantity. The force due to M_1 and M_2 are in opposite directions. Therefore, the resultant force is the subtraction of the two forces, i.e. $\frac{GM_1M_3}{x^2} - \frac{GM_2M_3}{(d-x)^2}$ Gravitational potential energy is a scalar quantity. The GPE due to presence of M_1 is $-\frac{GM_1M_3}{x}$ and due to presence of M_2 is $-\frac{GM_2M_3}{(d-x)}$. The resultant GPE is the sum of these two scalar quantities, i.e. $-\frac{GM_1M_3}{x} - \frac{GM_2M_3}{(d-x)}$
14	**D**	Option A is incorrect. The GPE of the spacecraft initially is negative and is increasing to zero as it approaches infinity. Option B is incorrect. The speed of the spacecraft should be decreasing as it continues to experience gravitational force from the planet. Option C is incorrect. The objects continue to experience gravitational force from the planet. Option D is correct. The objects experience a decreasing amount of gravitational force until zero at infinity.

15	**D**	 $E_1 = E_2$, $E_2 > E_3$ Hence vector addition of E_1, E_2 and E_3 gives the resultant electric field that is in direction of D.
16	**B**	$V = \frac{Q}{4\pi r}$ $Vr = \frac{Q}{4\pi}$ = constant $V(2) = (V / 4)(r)$ r = 8.0 m
17	**B**	The magnetic field forms concentric circles around the current and the direction can be determined using right hand grip rule. Gripping a current that is flowing out of the plane at P will form a magnetic field that is anticlockwise. At position O, the direction of the field will be the direction of the tangent drawn at O on the concentric circle, which is in OX direction. Option A gives a field in XO direction at O. Option C gives a field in OY direction at O. Option D gives a field in YO direction at O.
18	**D**	The direction of the magnetic field in the axis of the solenoid is parallel to the axis. The electron is thus moving parallel to the magnetic field, hence, there should be no electromagnetic force acting on the electron.
19	**D**	$P = I^2 R$ ..... (1) $2P = (I / 2)^2 R_{new}$ ..... (2) (2) / (1): $R_{new} = 8R$

20	**A**	Let the e.m.f of driver cell be E_1. Let the e.m.f of the secondary cell be E_2. The length of the entire wire be L. When connected to Y at balance point: $\frac{400}{L} \times E_1 = \frac{100}{100 + R} E_2$ ..... (1) When connected to Z at balance point: $\frac{600}{L} \times E_1 = E_2$ ..... (2) (1) / (2): $\frac{400}{600} = \frac{100}{100 + R}$ R = 50 Ω
21	**B**	 4.5 = 15 x I + $V_{thermistor}$ I = (4.5 − $V_{thermistor}$) / 15 Plot a line of I = (4.5 − $V_{thermistor}$) / 15 on the same graph. When both lines meet, the Y co-ordinate of the point gives current flowing in circuit.
22	**B**	

		p.d across voltmeter = p.d across C – p.d across A = (2R/3R) x 9 – (R/3R) x 9 = 3 V
23	**B**	Since <1/2 m v^2 > = 3/2 kT, T is constant for two containers, therefore mean K.E. is same for both gases.
24	**A**	From pV = nRT, Plotting pV against T would yield a straight line with gradient nR passing through the origin.
25	**C**	In the air, the damping effect is reduced. Hence,the amplitude of oscillation is larger and the reasonance frequency will be higher.
26	**D**	Graph A: underdamped. Graph C: critically damped, where the car reaches equlilibrium rapidly. Graph D: overdamped, where the car takes a long time to reach equilibrium.
27	**D**	Progressive mechanical waves include longitudinal waves which could not be polarized.
28	**D**	q = $\frac{3T}{2}$; p = λ; v = $\frac{distance}{time} = \frac{\lambda}{T} = \frac{3p}{2q}$
29	**B**	$n\lambda = d\sin\Theta$ For 3rd order, $3\lambda = 5\,\lambda\sin\Theta, \Theta = sin^{-1}\frac{3}{5}$, For 2nd order, $2\lambda = 5\,\lambda\sin\Theta, \Theta = sin^{-1}\frac{2}{5}$ Difference in angle between 2nd order and 3rd order = 13.3
30	**B**	For string, L = $\frac{\lambda}{2}$ For L/2 closed pipe, L/2 = $\frac{\lambda}{4}$. Therefore, L = $\frac{\lambda}{2}$, same wavelength as that of string.
31	**B**	When the switched in closed, the electromagnet will set up a field around itself. When the ring swings towards the electromagnet, it experiences a change in magnetic flux, an emf is induced. By Lenz's law, the emf induced will oppose the change that is causing it. The induced emf will be in a direction such that the induced flux will oppose the change. The ring hence experiences an opposing force. The oscillation will thus be heavily damped.
32	**C**	There is decrease in inward flux linking the outer loop. Hence induced current will be clockwise to produce inward flux. induced current will eventually decreased to zero .
33	**D**	$V_{secondary}$ = 120 / 20 = 6 V $P_{secondary} = V^2 / R = 6^2 / 4$ = 9 W $P_{primary}$ = 9 W (100% efficient) $I_{primary} = P_{primary} / V_{primary}$ = 9W / 120V = 0.075A
34	**D**	For significant diffraction, $\lambda \sim d$ (atomic separation) According to de Broglie, $\lambda = h / (mv)$ $\Rightarrow v = 6.63 \times 10^{-34} \div (9.11 \times 10^{-31} \times 10^{-10}) = 7.3 \times 10^6$ m/s

35	**C**	This observation can be explained by wave theory
36	**D**	For the shortest spectral line, the energy difference between involved levels = $\frac{hc}{\lambda_1}$ For the longest spectral line, the energy difference between involved levels = $\frac{hc}{\lambda_2}$ Thus, the energy difference between levels for the third spectral line = $\frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$ Let the wavelength of this third spectral line be λ_3. Thus, the energy difference can also be expressed as $\frac{hc}{\lambda_3}$. We then have $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$
37	**D**	A: de-excitation of electron B: de-excitation of electron as well C: photoelectric effect D: stimulated emission
38	**C**	During reverse bias condition, the negative terminal is connected to the p-type semi-conductor. Holes in the p-type semi-conductor are attracted towards the negative terminal. This also explains why the depletion region widens. Thus, the p-type semiconductor becomes less positive and more negative.
39	**A**	Energy is released hence there is a loss in mass. The mass before fusion is greater. Using $E = \Delta mc^2$, $\Delta m = 5.8 \times 10^{-30}$ kg
40	**A**	Energy released = $BE_{product} - BE_{reactant}$ $= (2 \times 118 \times 8.5) - 236 \times 7.65$ MeV $= 225$ MeV

Parent's Signature ……..

Candidate's Name …… CTG ……..…

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2016

PHYSICS **9646/2**
HIGHER 2 **19 August 2016**
Paper 2 **Friday**
Short Structured Questions **1 hour 45 minutes**

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INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.
Write your name and CTG in the spaces provided above.

Answer all questions.

All working must be shown clearly in the spaces provided.

Paper 2	
Q1	/10
Q2	/6
Q3	/8
Q4	/10
Q5	/10
Q6	/16
Q7	/12
Penalty	
Total	
	/72
	%

This question paper consists of **12** printed pages.

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}
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	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
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	=	$x_o \sin \omega t$
transmission coefficient	T	=	$\exp(-2kd)$, where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Answer all questions. Show your workings clearly in the spaces provided.

1 A ball is thrown vertically upwards with velocity of 26 m s^{-1}. Fig. 1.1 shows the variation with time *t* of the velocity *v* of a ball from the moment it is thrown.

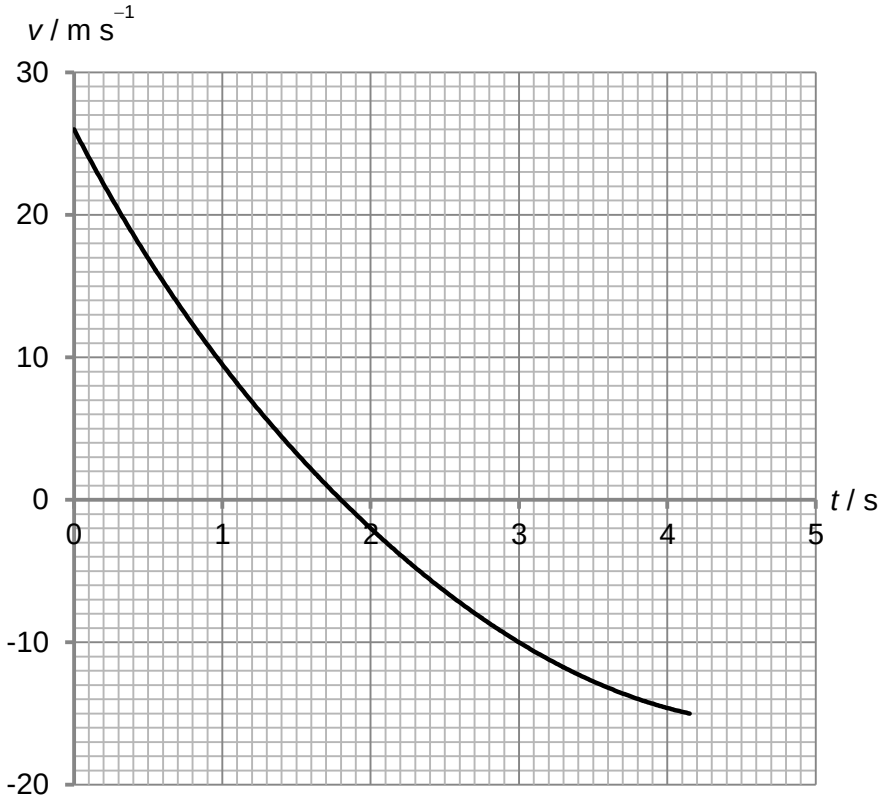


Fig. 1.1

(a) State the time at which the ball reaches its maximum height.

At max height, $v = 0$
From the graph, ***t* = 1.8 s** when $v = 0$.

time = ... s [1]

(b) Just after the ball leaves the thrower's hand, it has a downward acceleration of approximately 20 m s^{-2} which is much larger than *g*. Explain how this is possible.

Downward drag force due to air resistance is acting on it. [1]

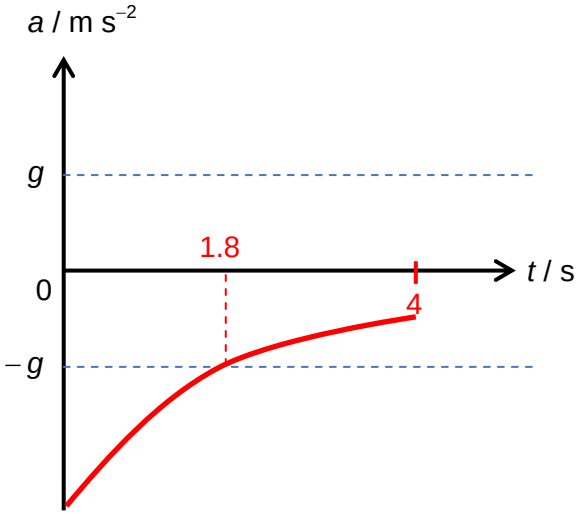
The resultant force which equals to the sum of the weight and the drag force is larger than the weight. [1] Hence the acceleration is larger than *g*. [2]

(c) It is found that the acceleration at t = 1.8 s is g. Explain how this is possible.

The velocity of object is zero, hence no drag force is acting on it. [1]

The resultant force acting on the object equals to the weight [1] Hence the acceleration equals to g. [2]

(d) Sketch the acceleration-time graph and displacement-time graph in Fig. 1.2 for the motion from t = 0 to t = 4 s, following the sign convention taken for the velocity-time graph in Fig. 1.1. The value of g is marked out in the acceleration-time graph. Label other critical values. [5]



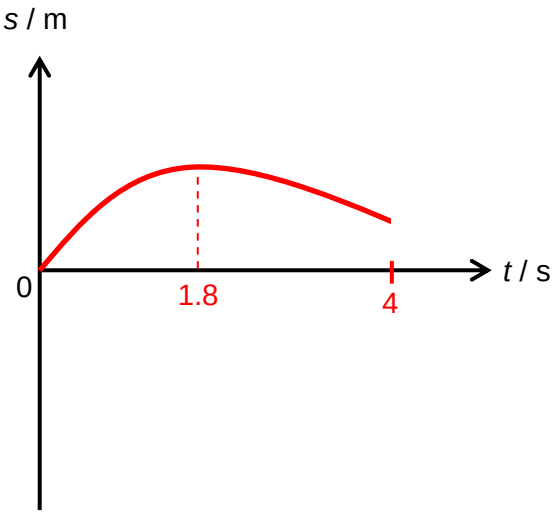
Max 3 marks

Curve with decreasing gradient – 1M

Shown cutting value of g at t = 1.8 s + labelling of 1.8 s & 4 s – 1M

Understanding the sign convention – 1M

If drawn cutting the time-axis at any point including t = 4s will have 1M



Max 2 marks

Asymmetrical curve skewed towards left – 1M

Shown max height at t = 1.8 s + labelling of 1.8 s & 4 s – 1M

2 A rectangular block of wood of cross-sectional area *A* and thickness *t* floats horizontally in water as shown in Fig. 2.1.

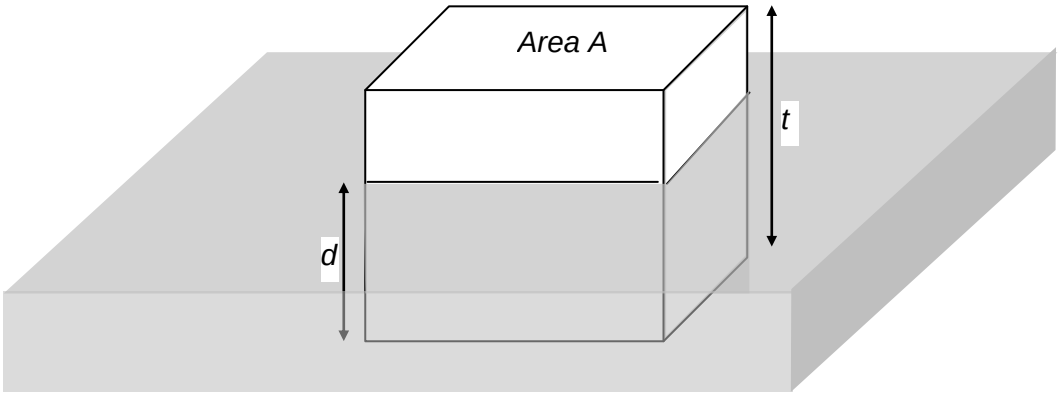


Fig. 2.1

The block floats when its lower face is at a depth *d* in the liquid of density ρ. The block experiences a force *F* on its lower surface as a result of immersion in the liquid.

(a) By considering the water pressure *P* exerted on the lower surface of the block, show that the force *F* is related to the volume *V* of the liquid displaced by the expression

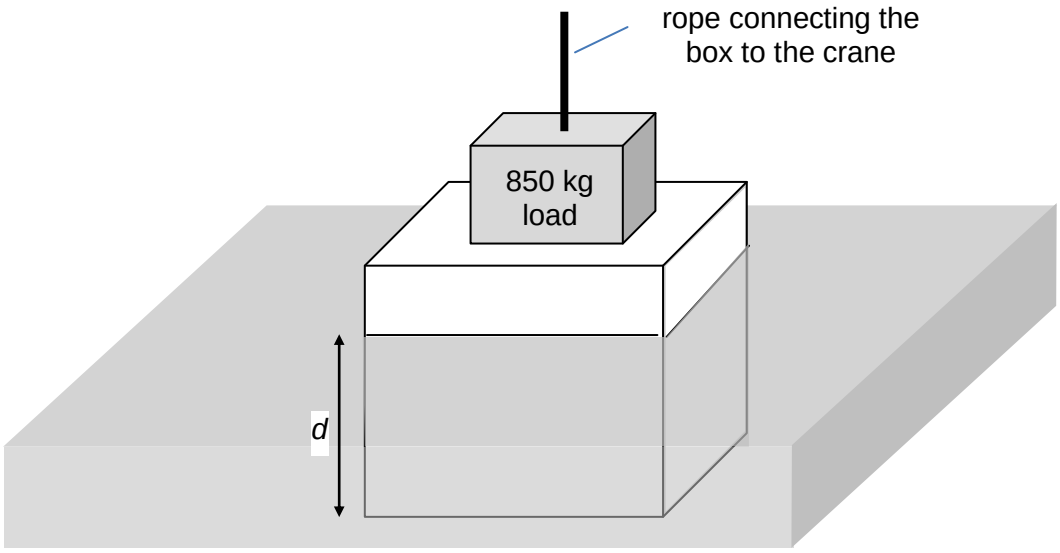
$$F = V \rho g$$

Water pressure at depth d
$P = \rho g d$ [1]

Since pressure = force / area
$F = P \times A$
$= \rho g d \times A$
$= \rho g V$ [1]

[2]

(b) A 850 kg load tied to a crane is placed on the rectangular block as shown in Fig. 2.2.



The block is further immersed in the water when the load is placed on it. The value of *d* changes from 70 cm to 95 cm.

Given that the mass of the block is 1500 kg and the density of the liquid is 1000 kg m^{-3}, determine

(i) the surface area *A* of the block,

Before the load is added
Force exerted by the water = weight of the block
$\rho_{water} V_{displaced} g = m_{block} g$
$1000 (0.7) A g = 1500 g$ [1]
$A = 2.14286$
$A = 2.14\ m^2$ [1]

surface area *A* = …… m^2 [2]

(ii) the tension in the rope.

Force exerted by block on box = $\rho_{water}\ V'_{displaced}\ g$ – weight of block
= $\rho_{water}\ V'_{displaced}\ g - \rho_{water}\ V_{displaced}\ g$
= $\rho_{water}\ (A \times \Delta d)\ g$
= 1000 (2.14286)(0.25)(9.81)
= 5255.36 N [1]

Tension = Weight – Force by block
= 850 (9.81) – 5255.36
= 3083
= 3100 N [1]

tension = …… N [2]

3 **(a)** Fig. 3.1 shows a circular open-air swimming pool of radius 15 m.

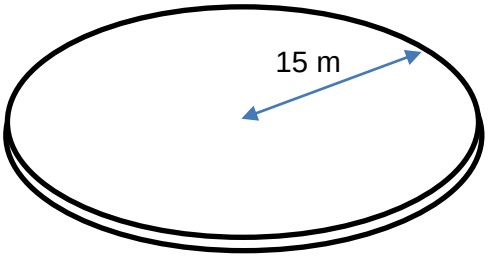


Fig. 3.1

The mass of water in the pool is 6.5 x 10^5 kg. A heater running at 90 kW is used to maintain the temperature of the water at 30 °C. The specific heat capacity of water is taken to be 4200 J kg^{-1} K^{-1}.

(i) When the heater is switched off for maintenance, the temperature of the water falls slowly to the surrounding temperature. Show that the initial rate of fall of temperature is about 0.1 °C per hour. [3]

Power needed to maintain temperature = 90 kW
This means that the water will be losing 90 kJ of heat in 1 second when the heater is switched off. [1]

In 1 second, temperature will drop by
$Q = mc\Delta\theta$
$90 \times 10^3 = 6.5 \times 10^5 (4200)\ \Delta\theta$
$\Delta\theta = 3.29 \times 10^{-5}$ °C [1]

In 1 hour, temperature will drop by
$\Delta\theta = 3.29 \times 10^{-5} \times 3600$ [1]
$= 0.118$

(ii) The maintenance usually takes about 3 hours. The rate of fall of temperature depends on the temperature difference between the water and the surrounding. With reference to part **(i)**, suggest why the rate of fall of temperature can be said to be constant during the maintenance.

The rate of fall of temperature is very small, therefore the temperature change within the 3 hours is very small. [1] The rate of fall of temperature which depends on the difference in temperature of the water and the surrounding will hence remain relatively the same. OR the temperature difference between the surrounding and the water remains relatively constant [1] [2]

(b) A cylinder, 0.50 m long and of cross-sectional area S, closed at each end, is fitted with a smooth thermally insulating piston, so as to contain gas in each segment A and B as shown in Fig. 3.2.

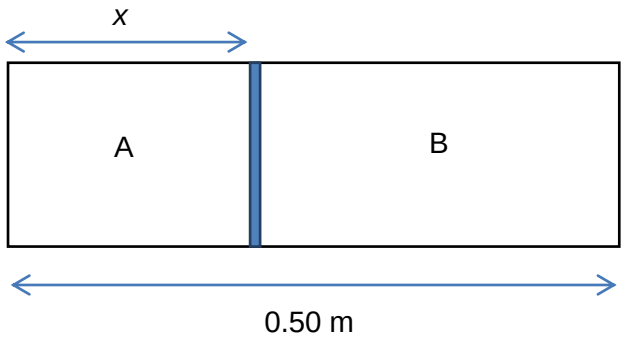


Fig. 3.2

The initial temperature of the gas in both segments is 27 °C and the distance *x* is found to be 0.20 m.

Determine the new distance *x*′ when the temperature of the gas in segment A is increased to 250 °C while keeping the temperature of the gas in segment B at 27 °C.

Initially,

$P_AV_A = n_ART_A$ $\quad P_BV_B = n_BRT_B$

$P_Ax_A\ A = n_ART_A$ $\quad P_Bx_B\ A = n_BRT_B$

$n_A / n_B = x_A / x_B$

$n_A = 2/3\ n_B$ [1]

When T_A becomes 250 °C,

$P_Ax_A\ A = n_AR\ (250 + 273)$ $\quad P_Bx_B\ A = n_BR\ (27 + 273)$

$$\frac{x_A}{x_B} = \frac{n_A(250+273)}{n_B(27+273)}$$ [1]

$$\frac{x_A}{x_B} = 1.162 \quad \text{------(1)}$$

$x_A + x_B = 0.50$ -------(2)

Solving (1) & (2)

$x_A = 0.269 = 0.27$ m [1]

distance *x*′ = ……. m [3]

4 A cork, P, floats on the surface of a pond. When a wave travels over the surface, the cork oscillates vertically with simple harmonic motion. The cork completes 20 oscillations in 24.0 s and has a total vertical range of 1.6 cm. Fig. 4.1 below illustrates its motion.

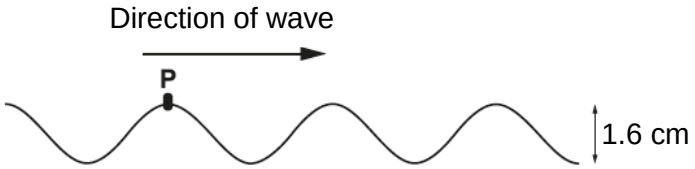


Fig. 4.1

(a) Define *simple harmonic motion*.

a) Acceleration is
- directly proportional to the displacement from a fixed point [1]
- directed towards the fixed point [1]

(b) Show that the angular velocity, ω, of oscillation is approximately 5.2 rad s^{-1}. [1]

(b) $\omega = 2\pi \div (24/20)$ [formula and subs – 1]
$= 5.24$ rad/s $= 5.2$ rad/s (to 2 s.f.)

(c) Given that x is the displacement of the cork from its equilibrium position at time t and that the cork is at the highest point when $t = 0$, determine the expression for x in cm, taking **downwards** as positive. [2]

(c) $x = -x_o \cos \omega t$ [cosine and negative – 1]
$\Rightarrow x = -0.8 \cos (5.2\, t)$ [subs – 1]

(d) Determine the time it takes for the cork to move directly downward from a point 0.40 cm above the centre of oscillation to a point 0.30 cm below the centre.

$-0.4 = -0.8 \cos(5.2\, t_1) \Rightarrow t_1 = 0.201$ s [1]
$+0.3 = -0.8 \cos(5.2\, t_2) \Rightarrow t_2 = 0.376$ s
Thus, time taken = 0.376 – 0.201 = 0.175 s [1]
[Allows ecf]

time taken = ... s [2]

(e) A second cork, Q, also oscillates on the surface at a quarter of a wavelength from P as shown in Fig. 4.2 below.

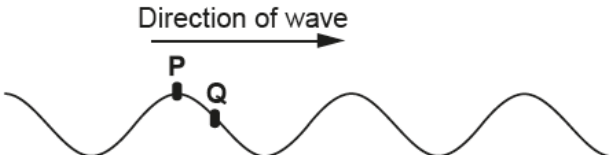


Fig. 4.2

In Fig. 4.3 below, draw the vertical displacements of the two corks during the time interval $t = 0$ to $t = 2.4$ s. Use the same axes for both graphs and label them clearly as P and Q. [3]

Negative cosine graph for **P** [1]
Negative sine graph for **Q** [1]
Same amplitude and period, two cycles, correct amplitude and period [1]
Allows ecf

Fig. 4.3

5 **(a)** Faraday's law of electromagnetic induction predicts that the induced emf, E, in a coil is given by $E = -\frac{dN\phi}{dt}$.

(i) State the physical quantity represented by the symbol ϕ.

magnetic flux .....[1]

(ii) Define *weber*.

One weber is defined by the product of the magnetic field strength of 1 T normal to the surface and the area of the surface of 1 m^2 .....[1]

(b) In Fig 5.1, the magnet forms the bob of a simple pendulum. The magnet oscillates with a small amplitude along the axis of a 240−turns coil that has a cross−sectional area of 2.5×10^{-4} m^2.

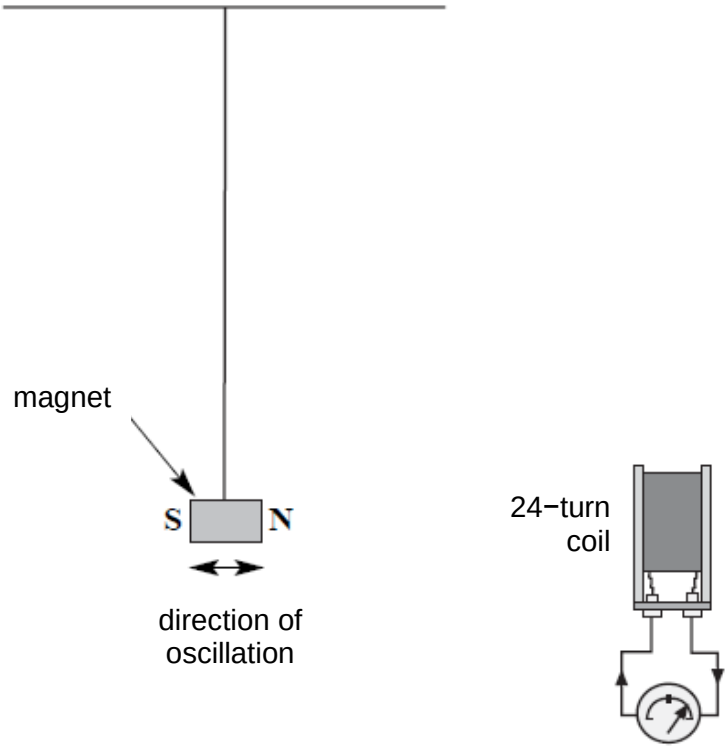
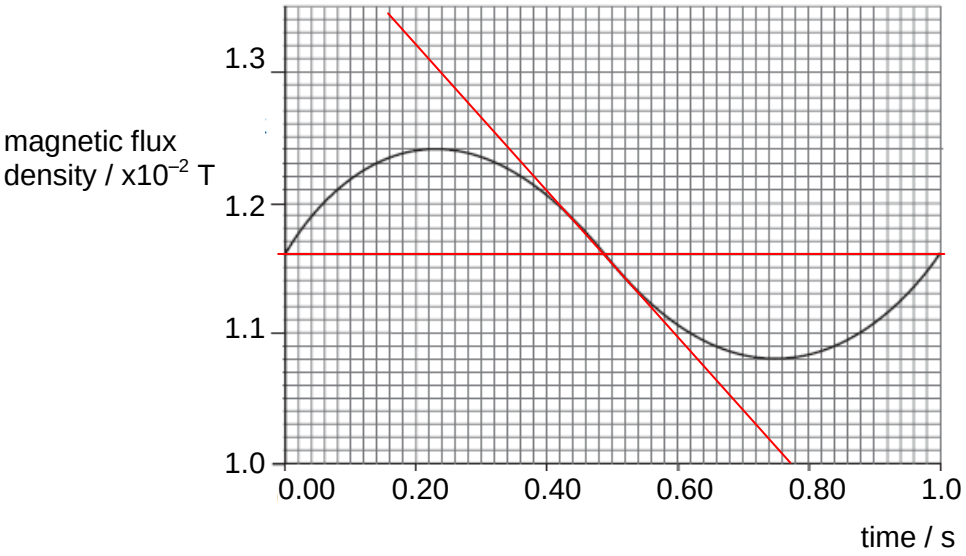


Fig. 5.1

Fig. 5.2 shows how the magnetic flux density, B, through the coil varies with time, t, for one complete oscillation of the magnet.



(i) Calculate the maximum e.m.f. induced in the coil.

max dB/dt determined using tangent drawn at t = 0, 0.5 s or 1.0 s (value should be in range 0.5 x 10^{-2} T s^{-1} to 0.7 x 10^{-2} T s^{-1})

emf induced = Δ(*BAN*)/ Δ *t*
= 240 x 2.5 x 10^{-4} x dB/dt = 0.3 mV - 0.42 mV

maximum e.m.f. induced = …… V [3]

(ii) The frequency of oscillation of the magnet is increased without changing the amplitude.

Explain, using Faraday's law of electromagnetic induction, what happens to the **maximum** e.m.f. induced.

maximum induced emf increases. [1]
Increasing frequency of oscillation indicates that the magnet will approach and leave the coil within a shorter time frame. [1] therefore Δ *t* is smaller.

Hence this will increase the rate of change of magnetic flux linkage through the coil. [1] Hence greater max e.m.f.

[3]

(iii) State **two** other ways of increasing the maximum induced emf.

use a stronger/more powerful magnet
use a coil with more turns (DO NOT allow more coils)
use a coil with greater cross sectional area (Not magnet with greater area)
use a soft iron core in the coil
use a larger amplitude of oscillation of the magnet

[2]

6 The decay of a radioactive substance can be represented by the equation

$$A = A_0 e^{-\lambda t}$$

where A = the activity of the sample at time t
A_0= the initial activity at time t = 0
λ = the decay constant

The half life, $t_{½}$ of the radioactive substance is given by

$$t_{½} = \frac{\ln 2}{\lambda}$$

An experiment was performed to determine the half-life of a radioactive substance which was a β-emitter. The radioactive source was placed close to a detector. The total count for exactly 5 minutes was recorded. This was repeated at 20-minute intervals. The results are shown in Fig. 6.1 below.

time, *t* / minutes	**total count, *C*, recorded in 5 minutes**	**count rate, *R* / minute^{-1}**	**corrected count rate, R_C / minute^{-1}**	**ln (R_C / minute^{-1})**
0	1016	203	183	5.209
20	892	178	158	5.063
40	774	155	135	4.905
60	665	133	113	4.727
80	608	122	102	4.625
100	546	109	89	4.489

Fig. 8.1

(a) A correction has been made to the count rate, R, to give the corrected count rate, R_C.
Explain why this correction has been made and deduce its value from the table.

(a) Background radiation present [1]

Background count = 20 counts/minute [unit required] [1]

.....
.....
.....[2]

(b) **(i)** Complete the table for t = 60 minutes. [2]

(ii) On Fig. 6.2, plot the point corresponding to t = 60 minutes and draw an appropriate straight line through all the plotted points. [1]

(c) Determine the gradient G of your graph.

Distance between gradient points must be more than half the length of BFL (from 1st to last point) [1]

Correct gradient coordinate values, read from graph [1]

Gradient correctly calculated [1]
[must have –ve sign and must be to 2 or 3 sf]

No unit penalty.

G = ……[3]

(d) Use your graph to determine the half-life (in minutes) of the radioactive substance used in this experiment.

Recognises gradient = (–) λ [1]

$T_{½}$ correctly calculated [to 2 or 3 sf] [1]

half-life, $T_{½}$ ..... minutes [2]

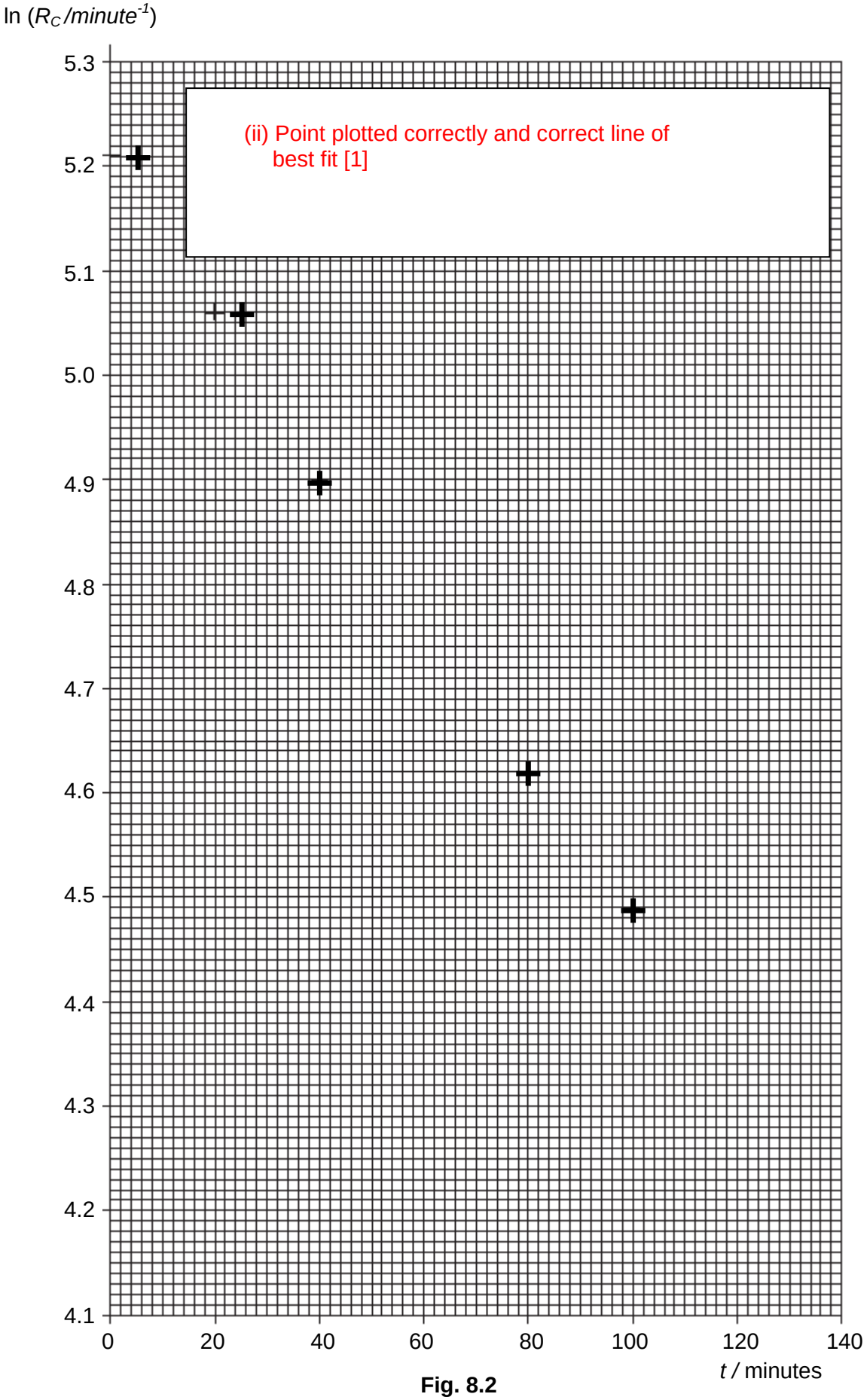

ln (R_C /minute^{-1})
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
0
20
40
60
80
100
120
140
t / minutes
(ii) Point plotted correctly and correct line of best fit [1]

Fig. 8.2

(e) Due to the nature of a radioactive decay there will be an uncertainty in the total count recorded. State this type of error.

Random [1] ..... [1]

(f) **(i)** It can be shown that the error in the total count C, is given by

$$\text{uncertainty in total count } C = \pm \sqrt{C}$$

Using data from the table, calculate the uncertainty in the **smallest** total count, C.

Uncertainty = ($\pm \sqrt{546}$) = $\pm$ 23 $\approx$ 30 [1]

[to 1 s.f.; 20 not accepted]

(ii) Hence calculate the percentage uncertainty in the **smallest** total count, C.

% uncertainty = ± 4.2% or ± 4.3 % [1]

3 sf : penalty

percentage uncertainty = ……[1]

(iii) Another student performed the same experiment with identical equipment but took total counts over a 1-minute period rather than a 5-minute period. The total count, C, at 100 minutes was 110 counts. Estimate the percentage uncertainty in this total count, and hence explain the advantage of using a larger time.

% uncertainty for 110 counts is ± 9.5% [1]

Taking data over larger time period / larger total count will have smaller percentage uncertainty. [1]

Accept ±10%

(g) Describe how the straight line graph would change if the radioactive substance had a longer half-life.

Longer half-life means a smaller λ. Thus line would be gentler. [1]

8 A **thermistor** is an element composed of semiconductor material which exhibits a large change in resistance proportional to a small change in temperature. The resistance of the thermistor is also dependent on the band gap of the semiconductor material used.

It is suggested that the variation of resistance R of the thermistor with temperature T is given by

$$R = Ae^{-E_g/kT}$$

where A is the initial resistivity of the thermistor (which is a constant),
E_g is the band gap of the semiconductor and
k is the Boltzmann's constant.

Design an experiment to determine the energy band of the material used in the thermistor in the range of temperature from 0 °C and 100 °C.

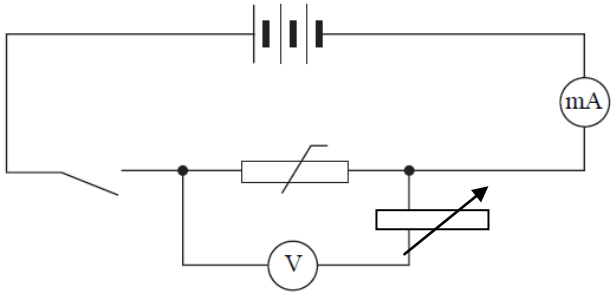
You may assume that you have the following equipment available, in addition to that normally found in a science laboratory.

thermistor	beaker
thermocouple	bunsen burner
variable resistor	voltmeter
ammeter	millivoltmeter

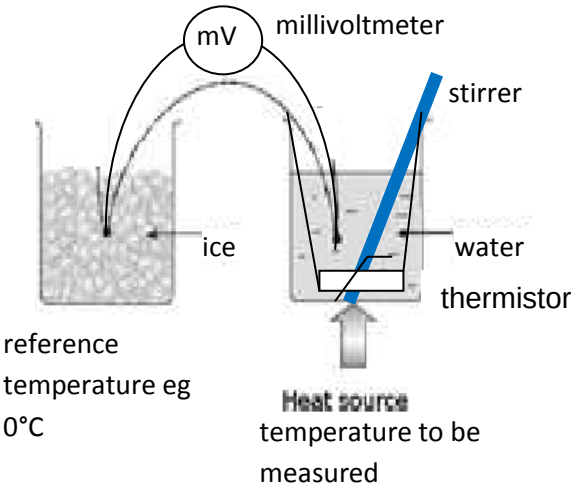
You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to :

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the resistance of the thermistor would be measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy/ reliability of the results obtained.

Control of variables: power supplied to the thermistor to be kept constant by varying the variable resistor such that $P = IV$ is kept constant. [1]
Diagram:



[1]- proper circuit connection containing thermistor.
[1] - for connection with ammeter and voltmeter



[1] - showing how thermocouple is connected

Connection of thermocouple.
1) Set up the apparatus
2) Place the thermistor in a beaker of cold ice at close to 0 °C with the thermocouple connected as shown. The left terminal of the thermocouple is immersed in ice which must be kept at 0°C. ----------[1]
3) Record the readings on the ammeter, I, and voltmeter, V.
4) Calculate the resistance of the thermistor using $R = V/I$. ----------[1]
5) Record the reading on the millivoltmeter, E (with thermocouple)
6) From the relationship, $E \propto \Delta T$. The temperature of the thermistor can be determined by comparing the reading E with the reading E_{100} when the left and right terminals are at 0°C and 100°C respectively using the following formula:

$$T = \frac{E}{E_{100}} \times 100 \text{ 0}$$ ----------[1]

7) Repeat step 3-6 by slowly heating up the beaker containing the themistor with low fire using bunsen burner until T reaches around 100°C.

Analysis: ln R = ln A - (Eg/k) (1/T)
Plot a graph of ln R against 1/T.
Gradient = E_g/k
E_g = k x Gradient ----------[1]

Safety aspect:
(1) Ensure no flammable objects are nearby [1]
(2) use dry hands when handling the circuit (eg switching on the circuit) **MAX: 1**

Reliability aspect:
(1) Record the reading *E* only when the temperature stops fluctuating or remains steady or the millivoltmeter does not show much fluctuation.[1]
(2) Continually stir the beaker with the thermistor to ensure uniform heating [1]
(3) repeat the experiment with increasing and decreasing temperature to ensure reproducibility of results. [1]
(4) Switch off the circuit when not taking any readings to avoid any overheating of wires which will introduce more resistance to the circuit. [1] **MAX : 3**

.....

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.....

.....

.....

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End of paper

YISHUN JUNIOR COLLEGE
JC 2 Preliminary Examinations 2016

PHYSICS **9646 / 03**

HIGHER 2

Paper 3 Structured Questions

MARK SCHEME AND SUGGESTED SOLUTIONS

1 A satellite of mass 80 kg is put into an equatorial orbit with an angular velocity equal to that at which the Earth rotates about its axis.

(a) Determine the angular velocity of the satellite.

$$\omega = \frac{2\pi}{T}$$

$$\omega = \frac{2\pi}{24 \times 60 \times 60}$$

$\omega = 7.27 \times 10^{-5}$

angular velocity = ... rad s^{-1} [2]

(b) Given the mass of Earth is 6.0×10^{24} kg, determine the radius of the satellite's orbit.

$$\frac{GMm}{r^2} = mr\omega^2$$

$$\frac{G(6.0\times10^{24})(80)}{r^2} = (80)r(7.27\times10^{-5})^2$$

$r = 4.23 \times 10^{7}$

radius = ... m [2]

(c) Assuming that this satellite experiences friction in the outer space, describe the subsequent motion of the satellite.

The satellite will spiral towards the Earth [1] with increasing speed. [1]

..... [2]

(d) It is generally possible to have a satellite orbit the earth from east to west as well as west to east. Explain why it is normally preferred to launch a satellite from west to east at the equator.

The Earth rotates from west to east. [1]

The satellite would have the (highest) linear velocity or kinetic energy due to the rotation of Earth at equator. [1]

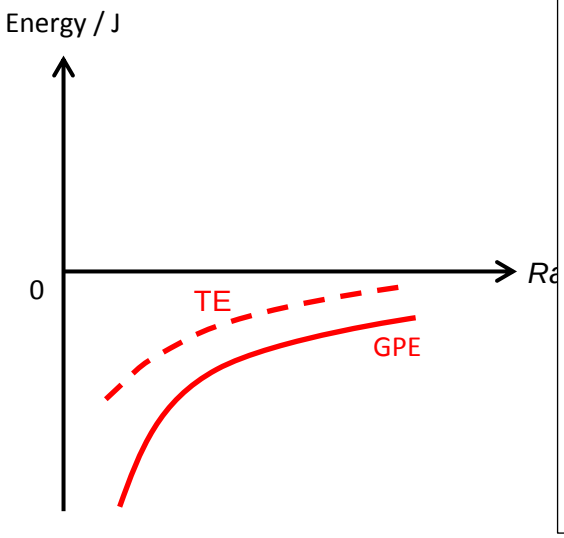
Hence less additional energy is required to launch the satellite into the required orbit. [1]

..... [3]

(e) Satellites orbiting with different orbital radii have different amount of gravitational potential energy, kinetic energy and total energy.

(i) Sketch on Fig. 1.1 the variation with orbital radius of the gravitational potential energy of orbiting satellites. Label the graph **GPE**. [2]

(ii) Sketch on Fig. 1.1 the variation with orbital radius of the total energy of orbiting satellites. Label the graph **TE**. [1]



GPE
Correct shape of graph – 1M

Drawn at negative side of the graph (only given if shape of graph is correct) – 1M

TE
Drawn nearer to axes than GPE – 1M

Award mark only if shape is correct.

Fig. 1.1

2(a) A common game in carnivals is the "high striker" whereby a player uses a hammer to hit a target pad at one end of a lever in order to launch a puck at the other end. The player wins if the puck hits the bell at the top of a tower. This is illustrated in **Fig. 2.1**.

In one such carnival, the hammer and puck weigh 9.00 kg and 0.40 kg respectively. The bell is located 5.00 m above the puck.

A student plays the game and just manages to ring the bell.

(i) Determine the gain in gravitational potential energy of the puck.

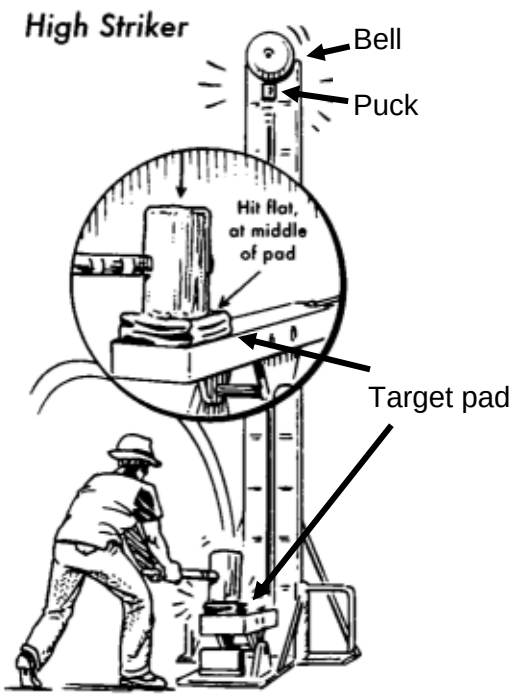


Fig. 2.1

Gain in gravitational potential energy = …… J [1]

(ii) Suppose that 75% of the final kinetic energy of the hammer is transformed into thermal and sound energy, calculate the speed of impact of the student's hammer on the lever.

speed of impact = ……. m s^{-1} [3]

(b) When a circuit is connected using an e.m.f. cell and external resistor, the following equation is used:

$$V = E - Ir$$

. whereby E is the e.m.f. of the cell, r is the internal resistance and I is the current in the circuit.

(i) State what V represents.

.....[1]

(ii) An ideal voltmeter connected across the terminals of a cell reads 1.61 V. The reading drops to 1.34 V when a 3.0 Ω resistor is connected in parallel with the voltmeter as shown in Fig. 2.1.

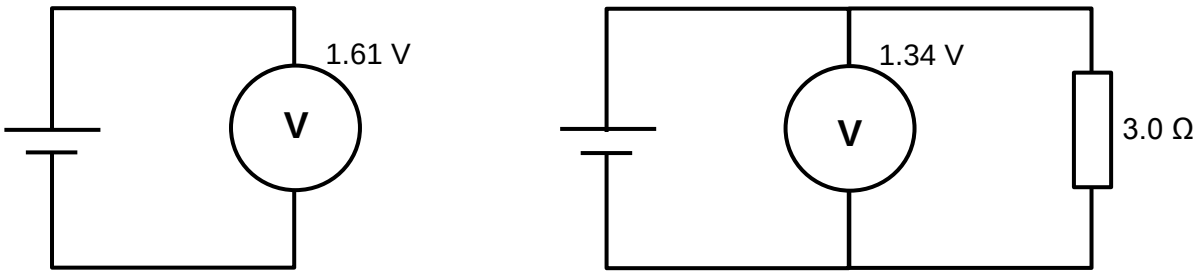


Fig. 2.1

1. Calculate the internal resistance of the cell.

internal resistance = ……. Ω [3]

2. A second resistor is connected in parallel with the 3.0 Ω resistor. Without doing any calculations, state and explain how *V* changes.

……

……

…… [2]

(a)

(i) Gain in g.p.e. of puck = *m g h*

= 0.4 × 9.81 × 5.00 [1]
= 19.6 J

(ii) 0.25 × Loss in k.e. of hammer = 19.6 [1]
⇒ 0.5 m v^2 = 78.4 [1]
⇒ v = 4.2 m/s [1]

(b) (i) The potential difference (p.d.) across the cell's terminals or p.d. across the resistor [1]

(i) 1. Since E = 1.61 V and V = 1.34 V, we have $I\,r$ = 0.27 V [1]

Given that $V = I\,(3)$ = 1.34 V, we have I = 0.4467 A [1]

Thus, (0.4467) r = 0.27 $\Rightarrow$ r = 0.60 Ω [1]

2. Effective external resistance decreases [1]

$\Rightarrow$ Draws more current from cell

$\Rightarrow$ "P.d. across r" increases, thus V decreases [1]

3 **Fig. 3.1** shows a p-type semiconductor placed in contact with another of n-type semiconductor, forming a P-N junction.

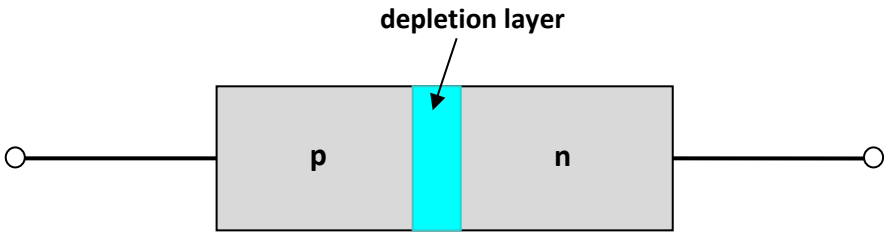


Fig. 3.1

(a) Explain what is meant by a depletion region in the P-N junction.

Depletion region is a region which is depleted of mobile charge carriers.

..... [1]

(b) Explain how the depletion region is formed between the p- and n-type semiconductor.

Since there is a higher concentration of electrons on the n-type semiconductor, the mobile electrons from the n-type semiconductor will diffuse towards p-type material. [1]

The mobile electrons leave behind *immobile positive ions* in the n-type semiconductor and combine with the Group 3 atoms to form the *immobile negative ions* in the p-type semiconductors. [1]

An internal E-field is set up within the depletion region and this prevents further diffusion of electrons across the junction. [1]

OR

Due to concentration gradient, the mobile electrons from the n-side and the mobile holes from the p-side flow across the junction and combine (no need to apply p.d.). [1]

This process leaves the n-side with a positive charge layer, and the p-side with a negative charge layer. [1] ..... [3]

The positive and negative charge layers on the 2 sides of the junction set up an electric field E in the junction. This electric field prevents any further movement of charge from the n-side and p-side across the junction. Hence, a depletion layer is formed. [1]

(c) The P-N junction (diode) is used as a rectifier in a circuit consisting of a 50 Hz, 240 V alternating sinusoidal voltage source as shown in Fig. 3.2.

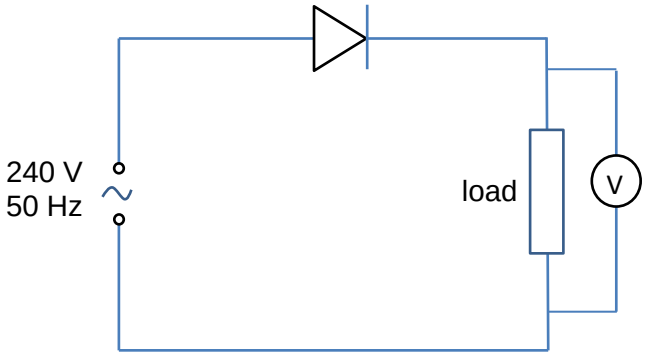
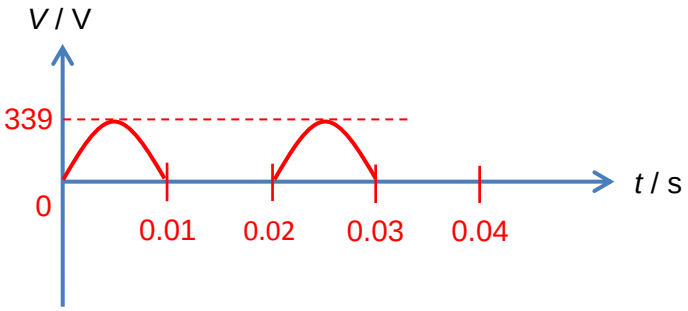


Fig. 3.2

(i) Sketch fully labelled graph to show variation with time of the voltage *V* across the load on Fig. 3.3. [2]



Rectified graph – 1M

Labelling of V_o and period – 1M

Fig. 3.3

(ii) Calculate the V_{rms} of the voltage across the load.

$\langle V^2 \rangle = \dfrac{\frac{1}{2} \times 339^2 \times 0.01}{0.02}$ = 28800[1]

$V_{rms} = \sqrt{28800}$ = 169.7 = 170 V [1]

V_{rms} = ... V [2]

4(a) Einstein's photoelectric equation appears in several forms, one of which is shown below:

$$E_{k\,\max} = h f - \phi$$

Monochromatic light of frequency 7.40×10^{14} Hz is irradiated onto a caesium surface, and $E_{k\,\max}$ is measured. The procedure is repeated for three other frequencies, enabling four points to be plotted on the graph grid of Fig. 4.1 below.

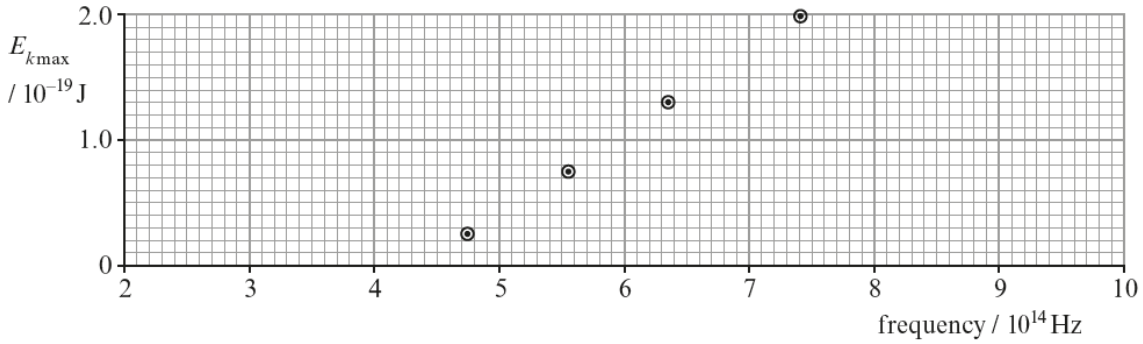


Fig. 4.1

(i) By showing your working, determine from Fig. 4.1

1. a value for the Planck constant,

Planck constant = …….. J s [2]

2. the threshold frequency of caesium.

threshold frequency = …… Hz [1]

(ii) When another metal surface is used instead of a caesium surface, $E_{k\,\max}$ is found to be 0.40×10^{-19} J for light of frequency 8.50×10^{14} Hz.

1. Draw the expected line of $E_{k\,\max}$ against frequency on the same grid in Fig. 4.1. [1]

2. Explain why visible light cannot be used to verify the expected line drawn in **(ii) 1.** experimentally and state the region of the electromagnetic spectrum required.

……

……

……..…[2]

(a)(i)

1. Gradient of graph gives Planck constant, h [1]

Value = 6.6 [± 0.3] × 10^{-34} J s [1]

2. Read off x-intercept = 4.4 [± 0.1] × 10^{14} Hz [1]

(ii)

1. Correct point plotted, parallel line [1]

2. The highest frequency of visible light range is 7.5 x 10^{14} Hz, whereas the threshold frequency of this second surface is about 7.9 x 10^{14} Hz, hence visible light's frequency is too low. [1] Ultraviolet region [1]

4(b) Fig. 4.2 illustrates how the potential energy E_p of an α-particle varies with distance r, measured along a line from the centre of a parent nucleus. R_o is the nuclear radius.

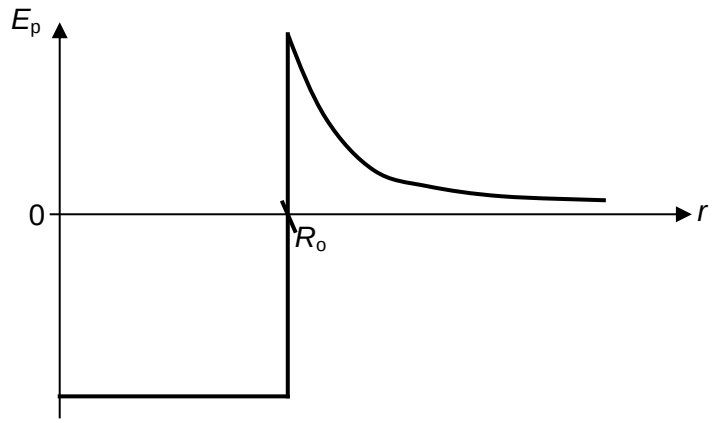


Fig. 4.2

Using this graph, suggest and explain how the energy of α-particles emitted is related to the length of the half-life of the parent nucleus.

.....

.....

.....

.....[4]

(b) Consider α-particles of high energy being emitted

→ barrier width shorter [1]

→ transmission coefficient greater [1]

→ shorter average waiting time before tunnelling [1]

→ shorter half-life [1]

Section B

Answer **two** questions from this Section

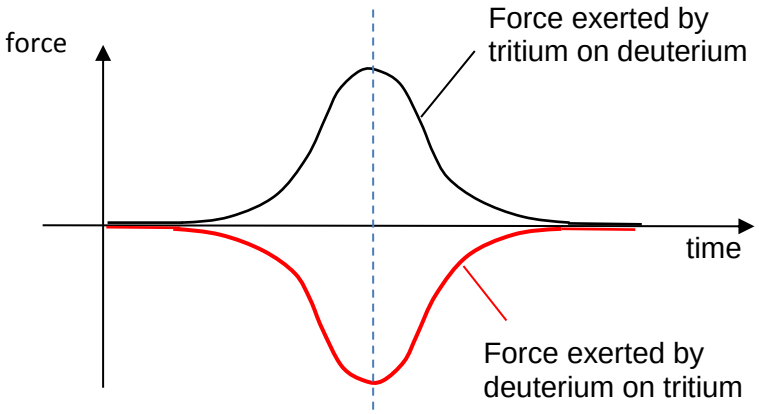
5 (a) A tritium nucleus moves towards a deuterium nucleus at a large distance from deuterium nucleus as illustrated in Fig. 5.1.



Fig.5.1

The nuclei initially have the same speed *v*. The tritium nucleus consists of two neutrons and a proton. The deuterium nucleus consists of a neutron and a proton. The proton and neutron are assumed to have the same mass *m*.

(i) Fig.5.2 shows the electric force exerted by tritium nucleus on deuterium nucleus during the interaction. Draw the electric force exerted by deuterium nucleus on tritium nucleus in Fig. 5.2.



[1]

Fig. 5.2

(ii) Explain your answer to **(i)**.

According to Newton's third law, when tritium nucleus exerts a force on deuterium nucleus, deuterium nucleus will also exert a force of an equal magnitude but in opposite direction on tritium nucleus. [1]

……

……

…… [1]

(iii) Explain how your answer to **(i)** is consistent with the principle of conservation of momentum.

Principle of conservation of momentum states that the total momentum of a system will be constant if the total net external force acting on the system is zero. [1]

Area under force –time graph gives the change in momentum. [1] Since the areas under force –time graph for tritium and deuterium nuclei have the same magnitude but are of opposite sign, [1] the sum of both the change in momentum of tritium and deuterium nuclei be equal to zero. Hence the total momentum of tritium and deuterium nuclei remains constant.

…… [3]

(iv) Determine the final speed of tritium nucleus in terms of v.

Applying Conservation of momentum:

Total momentum before = Total momentum after

$$(3\,m)\,v + (2\,m)\,(-v) = (3\,m)\,v_T + (2\,m)v_D$$

$$v = 3\,v_T + 2v_D \quad \text{.....(1)} \qquad [1]$$

Relative speed of approach = Relative speed of separation

$$v - (-v) = v_D - v_T \qquad [1]$$

$$v_D = v_T + 2\,v \quad \text{.....(2)}$$

Substitute (2) into (1) to solve for v_T:

$$v = 3\,v_T + 2(v_T + 2\,v)$$

$$v_T = -0.6\,v \qquad [1]$$

Speed = …… [3]

(b) **(i)** Define electric field strength.

Electric field strength at any point is the force per unit charge acting on a small positive test charge placed at that point.

……

…… [1]

(ii) Fig 5.3 shows a charge +*q* at X in a uniform electric field of strength *E*.

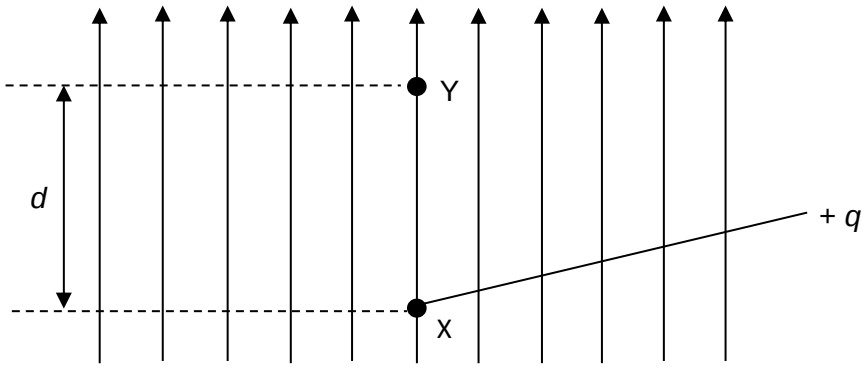


Fig. 5.3

` The charge at X is moved to Y through a distance *d*. Use your definition in **(i)** to deduce an expression for the work done by external force.

Work done by external force = $F_{external}$ x d

= (– *E* x *q*) x *d*

= – *E q d* [1]

Work done = …… [1]

(iii) The potential difference between X and Y is *V*. Using your answer from **(ii)**, deduce an expression for the magnitude of *E* in terms of *V* and *d*. [1]

V = W / q = (*E q d*) / q = *E d*

E = *V* / *d* [1]

(c) A stream of nuclear particles, travelling horizontally at 4.5 x 10^6 m s^{-1}, is deflected as it passes through a vacuum between two parallel plates as shown in Fig. 5.4.

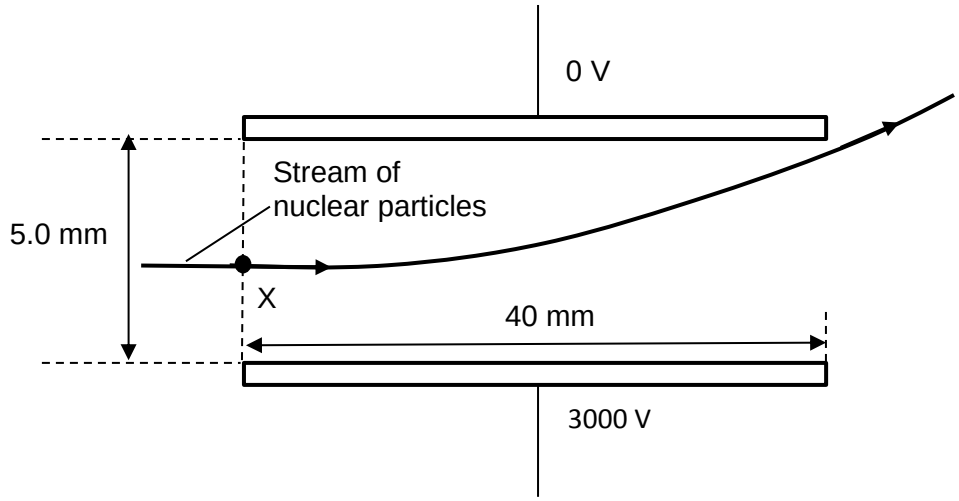


Fig. 5.4

The separation of the plates is 5.0 mm, their length is 40 mm and the potential difference across the plates is 3000 V. The vertical displacement of the particles against the horizontal displacement is shown in Fig. 5.5. The horizontal displacement is measured from point X when it just entered the plate.

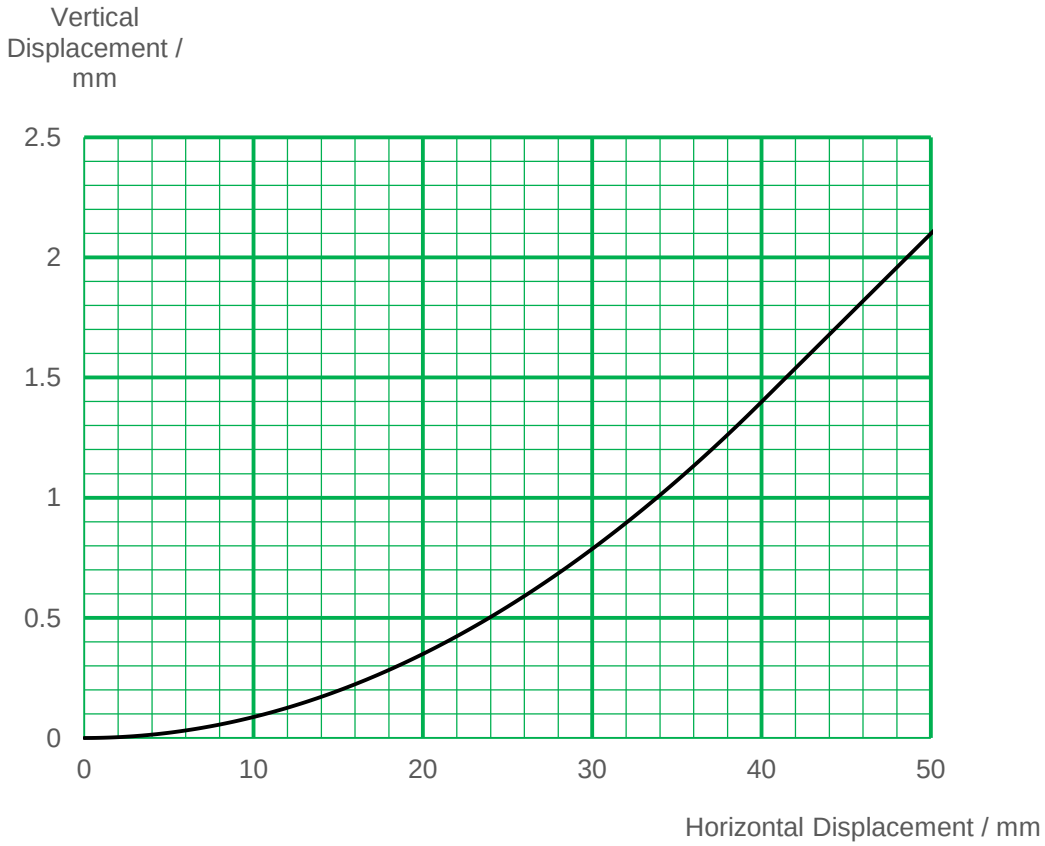


Fig. 5.5

(i) Calculate the time for which the particle is between the plates.

time = s_x / u_x

= 40 x 10^{-3} / 4.5 x 10^{6}

= 8.89 x 10^{-9} s [1]

time = ... s [1]

(ii) Determine the vertical acceleration from graph shown in Fig. 5.2.

When the horizontal displacement = 40 mm, the vertical displacement = 1.40 mm at t = 8.89 x 10^{-9} s

$s_y = u_y + 1/2\ a_y\ t^2$

1.40 x 10^{-3} = 0 + 1/2 a_y (8.89 x 10^{-9})^2 [1]

a_y = 3.54 x 10^{13} m s^{-2} [1]

Vertical acceleration = ... m s^{-2} [2]

(iii) Calculate the electric field strength between the plates.

E = V / d

= 3000 / 5.00 x 10^{-3} [1]

= 6.00 x 10^{5} V m^{-1} [1]

electric field strength = ... V m^{-1} [2]

(iv) Each nuclear particle carries a positive charge of 3.2 x 10^{-19} C. Using the value in **(ii)** and **(iii)**, calculate the mass of each particle.

$F = m\ a$

$q\ E = m\ a$

$m = q\ E\ /\ a$

= (3.2 x 10^{-19}) x (6.00 x 10^{5}) / (3.54 x 10^{13}) [1]

= 5.42 x 10^{-27} kg [1]

mass of particle = ... kg [2]

(v) State and explain what would happen to the deflection of the nuclear particles if the separation between the plates decreases.

The electric field between the plates will be larger. [1]

Hence the net force and acceleration experienced by charged particles in upward direction will be higher. The deflection of the particles will be larger. [1]

…… [2]

6(a) What is meant by the following terms in italics?

(i) *coherent* sources

……

……[1]

(ii) *phase difference*

……

……[1]

(iii) *diffraction*

……

……[1]

(b) **(i)** State the conditions for a well-defined stationary wave to be formed using two separate sound sources.

……

……

……[2]

(ii) Compare the amplitude, phase and frequency of the motion of particles between a stationary and progressive wave.

……

……

……

…….....

…….....[5]

(c) In Fig. 6.1, a straight road runs parallel to the line joining two radio transmitting aerials A and B which are 600 m apart. Both aerials radiate signals at a frequency of 50 MHz. The road is 4.8 km from the aerials at its nearest point X.

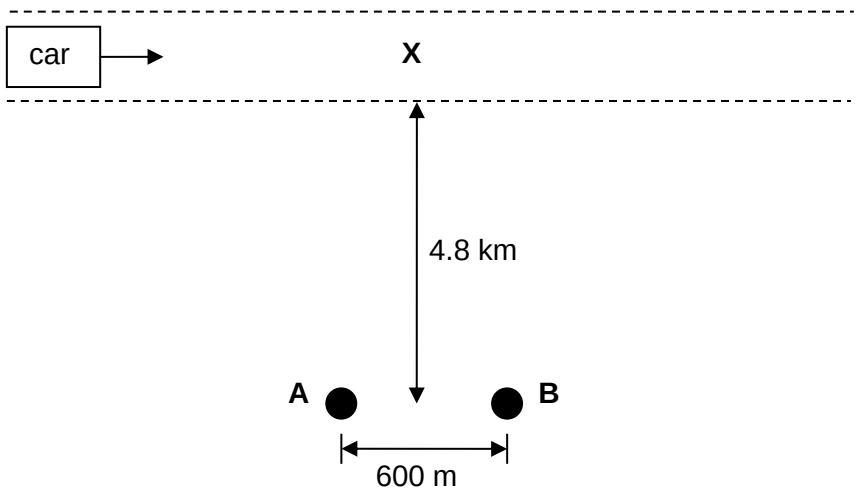


Fig. 6.1

A car travels at a steady speed along the road. As it passes along the road, it receives a radio signal which varies its intensity periodically.

(i) Explain why the intensity of the radio signal received varies as described.

…….....

…….....

…….....[3]

(ii) It is found that the maximum intensity of the radio signal is received at a frequency of 0.50 Hz. Calculate the speed of the car.

speed of car = ……..... m s^{-1} [3]

(d) In **Fig. 6.2**, $\mathbf{S_1}$ and $\mathbf{S_2}$ are two coherent point sources placed at a distance d apart.

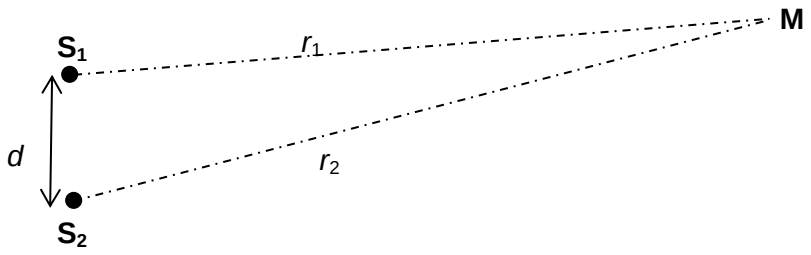


Fig. 6.2

The sources emit waves that are in phase. Each wave has an amplitude A and wavelength λ. The distances of **M** from $\mathbf{S_1}$ and $\mathbf{S_2}$ are r_1 and r_2 respectively.

(i) Deduce the ratios of the intensities and the amplitudes, in terms of r_1 and r_2, of the waves from $\mathbf{S_1}$ and $\mathbf{S_2}$ when they arrive at **M**. [3]

Ratio of intensities = ……..

Ratio of amplitudes = ……..

(ii) Hence or otherwise, explain why there is no complete cancellation of the two waves if they arrive at **M** and are at anti-phase to each other.

……

……[1]

6(a) (i) *coherent* refers to sources that produce waves of constant phase difference. [1]

(ii) *Phase difference* refers to the difference in the stages of oscillation for one cycle. [1]

(iii) *diffraction* refers to the phenomenon of bending or spreading of waves when they pass an obstacle or through an aperture. [1]

(b) (i) The waves from the two separate sound sources must have equal amplitude and frequency [1] and travel with the same speed in opposite direction [1]

(ii)

	Stationary Wave	Progressive Wave
amplitude	varies from zero at the nodes to maximum at the antinodes.	same for all particles.
phase	all particles between 2 adjacent nodes are in phase. Particles between adjacent pairs of nodes are in anti-phase.	all particles within one wavelength have different phases.
frequency	all particles vibrate with same frequency as the wave (except those at the nodes).	all particles vibrate with same frequency as the wave.

Each point is worth 1 mark. Maximum of 5 marks.

(c) (i) Signals emitted from A and B undergo interference at different points along the road. [1]
When the phase difference is such that they in phase, constructive interference takes place and the intensity is a maximum. [1]
When the phase difference is such that they are anti-phase, destructive interference takes place and the intensity is a minimum.
Since the maxima and minima are equally spaced the signal intensity varies periodically along the road. [1]

(maximum of 2 marks to be given if the answer is in terms of path difference = $n\lambda$ for constructive interference or $(n+\frac{1}{2})\lambda$ for destructive interference)

(ii) wavelength of signal, $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{50 \times 10^6} = 6\ m$ [1]

Using $\lambda = \frac{ax}{D}$: $6 = \frac{600x}{4800} \Rightarrow x = 48\ m$ [1]

$v = f\lambda$ = 0.5 x 48 = 24 m s^{-1} [1]

(d) (i) since $I \propto A^2$ and $I \propto \frac{1}{r^2}$, then $A \propto \frac{1}{r}$ [1]

ratio of intensities $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ [1]

		ratio of amplitudes $\frac{A_1}{A_2} = \left(\frac{r_2}{r_1}\right)$ [1]
	(ii)	Since the amplitudes of the two waves arriving at P are not equal, the resultant amplitude at destructive interference is not zero. [1]

7 (a) A doubly-charged positive ion of the copper isotope Cu is projected into a vertical magnetic field of flux density 0.28 T as shown in Fig. 7.1. The magnetic field is directed upwards. The ion enters the field at a speed of 7.8×10^5 m s^{-1}.

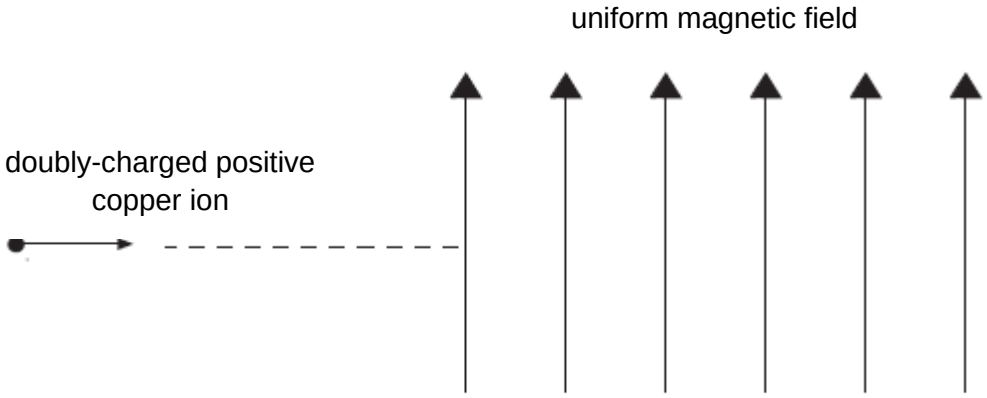


Fig. 7.1

(i) State the initial direction of the magnetic force that acts on the ion.

..... **out of the plane.** .....[1]

(ii) Describe the subsequent path of the ion as fully as you can. Your answer should include both a qualitative description and a calculation.

mass of $^{63}_{29}$Cu ion = 1.05×10^{-25} kg

Calculation:

$$BQv = \frac{mv^2}{r}$$

$$r\left(= \frac{mv}{BQ}\right) = \frac{1.05 \times 10^{-25} \times 7.8 \times 10^5}{0.28 \times 2 \times 1.6 \times 10^{-19}}$$

r = 0.914 m [2]

The ion will move in a <u>circular path</u> with axis of rotation parallel to the magnetic field at constant speed. [1] The radius of the path is 0.914 m.

.....

.....

.....[3]

(iii) State the effect on the path in part **(ii)** if the following changes are made separately.

1. The strength of the magnetic field is doubled.

..... **radius is halved or decreased** .....

.....[1]

2. A singly-charged positive Cu ion replaces the original one.

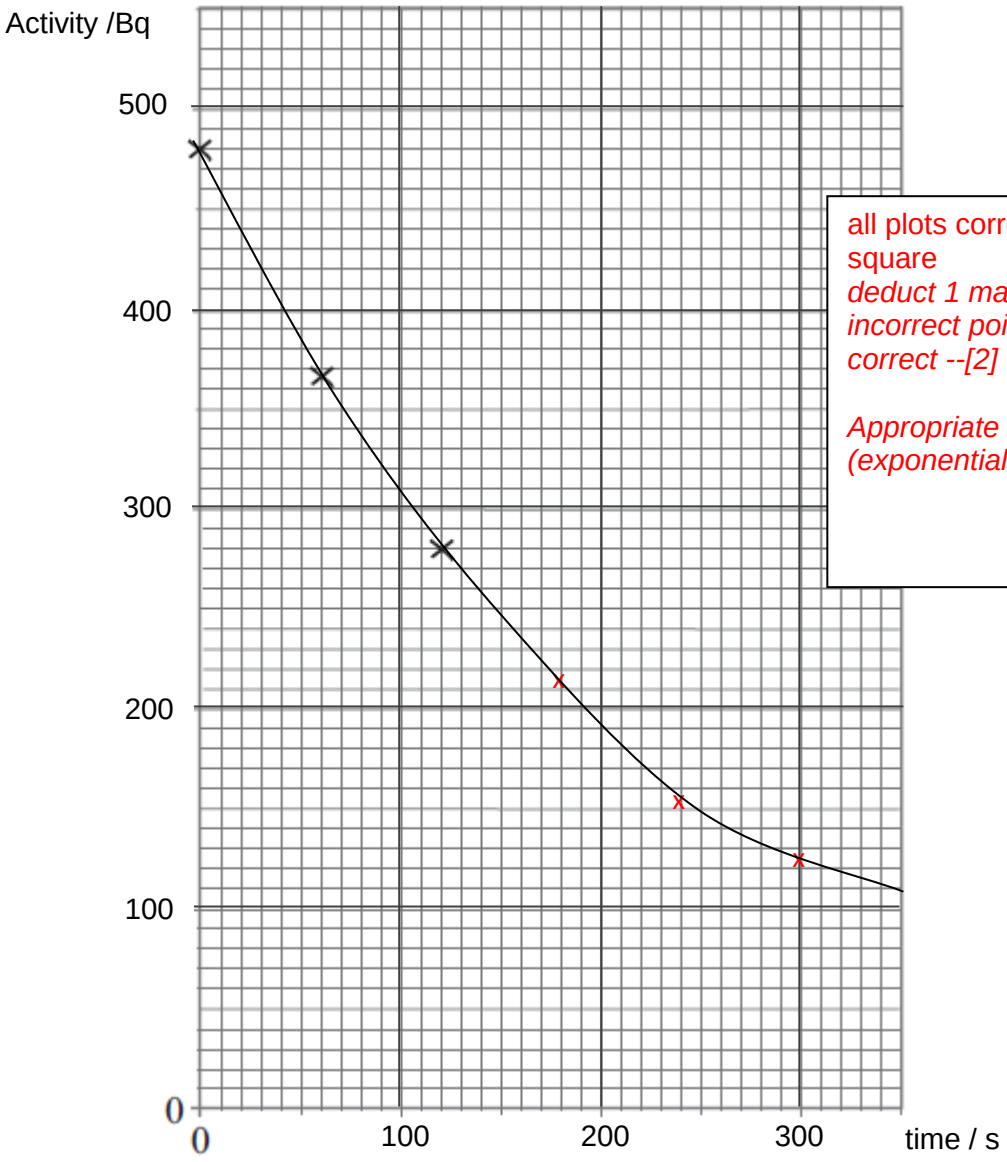
..... **radius is doubled.** .....

.....[1]

(b) The table below gives the values for the activity of a radioactive isotope over a period of a few minutes.

time/s	0	60	120	180	240	300
activity/Bq	480	366	280	214	163	124

(i) Complete the graph below by plotting the remaining points and drawing an appropriate curve.



all plots correct to ½ small square
deduct 1 mark for one incorrect point, all points correct --[2]

Appropriate line (exponential curve) -[1]

[3]

(ii) Use **the graph** to determine the half-life of the isotope. Show and explain your steps clearly.

candidates should determine the half life by reading off when activity = 240 Bq, $t_{1/2}$ is about 155s. [1]

candidate must determine the value of second half life when activity is 120 Bq which is 2 $t_{1/2}$ = 310, therefore $t_{1/2}$ = 155 s.

Must show average, average t = 155 ± 10 s (depending on the graph drawn) [1]

half-life ..... s [2]

(iii) Initially there were 1.1×10^5 atoms of the isotope present.
Calculate the decay probability of the isotope.

(use of $A = \lambda N$)
$480 = \lambda \times 1.1 \times 10^5$ [1]
$\lambda = 4.4 \times 10^{-3}$ [1]

[allow $\lambda = \ln 2/t$ ½] should arrive at the same answer or close to the same answer depending on the half life found in (b).

decay probability = ... s^{-1} [2]

(c) **(i)** Explain what is meant by binding energy.

Binding energy of a nucleus is the work done on the nucleus to separate it into its constituent neutrons and protons.

.....[1]

(ii) Calculate the binding energy of a thorium nucleus $^{226}_{90}Th$.

Given that rest mass of $^{226}_{90}Th$ = 226.0249 u

rest mass of proton = 1.0073 u

rest mass of neutron = 1.0087 u

Binding energy $\Delta E = \Delta mc^2$

= [(90 x 1.0073) + (136 x 1.0087) -226.0249] u c^2 [1]

= 2.712 x 10^{-10} [1]

= 1700 MeV [1]

binding energy = ... Mev [3]

(iii) A thorium nucleus $^{226}_{90}Th$ originally at rest decays and forms a radium nucleus $^{222}_{88}Ra^*$ and an alpha particle as shown below. The radium nucleus $^{222}_{88}Ra^*$ is in an excited state.

$$^{226}_{90}Th \rightarrow {}^{222}_{88}Ra^* + {}^{4}_{2}He$$

Given that

rest mass of $^{226}_{90}Th$ = 226.0249 u

rest mass of $^{222}_{88}Ra$ = 222.0154 u

rest mass of $^{4}_{2}He$ = 4.0026 u

Determine the kinetic energy of the radium nucleus if the alpha particle is emitted with a kinetic energy of 2.38 MeV.
Explain your working and state an assumption made in your calculations.

Energy released = Δmc^2

= [226.0249 -(222.0154 + 4.0026)]u c^2

= 1.0308 x 10^{-12} J

= 6.44288 MeV [1]

Assumption: this energy released comes only in the form of KE of the products. [1]

Energy released = KE of radium + KE of alpha particle

6.44288 MeV = KE_{Ra} + 2.38 MeV

KE_{Ra}= 4.06 MeV [1]

kinetic energy = ... J [2]

Assumption : .....

.....[1]